Effect of Triazole and Strobilurin Fungicides on Seed Yield and Grain Quality of Winter Rapeseed (*Brassica napus* L.)

Muhammad Ijaz

A thesis submitted for the requirement of doctoral degree in agriculture from
Faculty of Agricultural and Nutritional Sciences, and Environmental Management
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Dedicated to

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Contents

List of Figures

List of Tables

List of Appendices

List of Abbreviations

cm	centimeter
dt	decitones
FAO	Food and Agriculture Organization
FID	Flame Ionization Detector
FFA	Free Fatty Acids
GC	Gas Chromatography
GI	Giessen
GSL	Glucosinolates
Fun	Fungicides
g	gram
ha	hectare
K	Potassium
kg	kilogram
LAI	Leaf Area Index
LSD	Least Significant Difference
MB	Main-branches
mequ	Milliequvalent
NS	Non Significant
N	Nitrogen
P	Phosphorus
p	Probability
PH	Plant Height
PH_1	Height of main stem from soil surface to 1st internode
PIAF	Planning Information Analysis Program for Field Trials
PL	Pod length
P/Pl	Pods per plant
PV	Peroxides value
RCBD	Randomized Complete Block Design
RH	Rauischholzhausen
S	Sulphur
SB	Sub-branches
SD	Standard Deviations
S/pd	Seeds per pod
TGW	1000-grain weight

1. INTRODUCTION

Rapeseed (*Brassica napus* L.) is the most important cultivated crop for vegetable oil in Germany. It is the second edible oil source in the world (Raymer et al. 2002) and has not only more than 45% seed oil but also the lowest saturated fatty acids (5-8%) among all oilseed crops (Starner et al. 1996, Sovero et al. 1993). The value and utility of an oilseed crop for both nutritional and industrial purposes primarily depends upon the fatty acid composition of the seed oil. Efforts are being made to modify the oil composition, especially oleic acid. Moreover winter rapeseed is also considered to be an excellent rotation crop as it enhances suppression of soil-borne pathogens important rotation crop. According to FAO (2011) the global rapeseed production in 2010 was 59.1 million tons of which 23.1 million (39.1%) were produced in Europe and 5.7 million (9.7%) in Germany of world production (Appendix 1). Demands for rapeseed oil grew significantly in the developed world during the twentieth century with concurrent improvements in varieties, processing methods and agronomic techniques which also include optimal use of growth regulating fungicides.

Chemical growth regulations are used in rapeseed to achieve some of the growth targets which are required for potential seed yield. Plant growth regulators are compounds which are used to reduce plant growth without changing developmental patterns or being phytotoxic (Rademacher et al. 2000). The largest group of plant growth regulators consists of chemicals antagonistic to gibberellins (GA), the hormone that is responsible for plant growth (Fletcher et al. 2000). Triazoles fungicides are currently used on oilseed rape in Europe for both their fungitoxic and growth regulatory properties (Berry and Spink 2009, Fletcher et al. 1986). Triazoles affect the isoprenoid pathway and alter the levels of certain plant hormones by inhibiting gibberellins synthesis, reducing ethylene evolution and increasing cytokinin levels (Zhou and Leul 1998, Grossmann et al. 1994, Fletcher et al. 1988, Graebe 1987, Rademacher et al. 1983. Triazole inhibits mono-oxygenases which oxidize in three steps ent-kaurene to ent-kaurenoic acid an early reaction in GA biosynthesis (Rademacher et al. 2000, Hedden and Kamiya 1997). The target structure of mono oxygenases affected by triazoles is cytochrome P450 (Rademacher et al. 2000). The heterocyclic ring of a triazole- type molecule is essential for binding cytochrome P450. A lone electron pair on the Sp_2 hybridized nitrogen atom of heterocycle enables its interaction with cytochrome P 450 (Sadhu and Gupta 1997). The nitrogen of the triazole ring is located towards the central iron of porphyrin structure interacting with the site, which is normally occupied by the oxygen molecule. This interaction prevents mono-oxygenases from binding oxygen which would be normally activatedand transferred to the substrate (Sadhu et al. 1997, Grossman et al. 1990). In winter rapeseed triazole application reduced rate of photosynthesis by decreasing the stomatal conductance (Zhou and Ye 1996, Hauser et al. 1990). The inhibition of stem and leaf growth by plant growth retardants can alter the canopy architecture of winter oilseed rape by shortening the stem of plants and improve production efficiency by stimulating the formation of lateral flights and auxiliary buds, and by uniform ripening of pods. Plant growth retardants also diminish the risk of early lodging, and induce a degree of frost tolerance in winter rapeseed (Armstrong and Nicol 1991, Baylis and Wright 1990, Scarisbrick et al. 1985). Performance of triazole in combination with strobilurin and growth regulator trinexapac was considerable increased to improve seed yield by prolonging photosynthetic duration of green tissues in cereals (Bertelsen et al. 2001).

Strobilurins are systemic fungicides and these exert their fungicidal action by blocking electron transport in the mitochondrial respiratory chain in fungi (Balba et al. 2007). With this unique mode of action the strobilurin is an important addition to the existing fungicides, in which recent broad- spectrum fungicide products have been largely based on sterol biosynthesis inhibitors (SBI). Strobilurins have been shown to inhibit the germination and pre-penetration growth of several plant pathogens (Godwin et al. 1994), whereas triazole fungicides generally do not inhibit fungal growth until after initial infection (Hanssler and Kuck 1987). After the launching of strobilurins, and with the evolution of this group of chemical products, the concept of disease control gained new perspectives especially when considering the advantages obtained by the action of positive physiological effects on plants (Venancio et al. 2003). Research on the physiological effects of strobilurins on plants showed that strobilurins decrease ethylene production (Grossmann 1997). Lower ethylene concentrations have been shown to slow the degradation of cytokinins, resulting in delayed senescence (Bollmark eta al. 1990). Thus studies so far have concentrated mainly on phytohormone-mediated effects of strobilurins on the physiology of the plant senescence process. Therefore a longer period of photosynthetic active green leaf area has been suggested to be the main factor for yield increases obtained with strobilurin fungicides, because the increased photosynthetic period would increase the quantity of assimilate available for grain filling (Bertelsen et al. 2001). Triazole and strobilurin treatments associated various morphological and physiological changes in various plants; including inhibition of plant growth, decrease in internodal elongation, increased chlorophyll levels, enlarged chloroplast, thicker leaf tissue, increased root to shoot ratio, delayed senescence, increased antioxidant potentials and enhancement in alkaloid production (Zhang 2010, Ruske 2004; 2003, Wu and Tiedemann 2001). Over large canopies of winter rapeseed due to imbalance use of fertilizers can be optimized by using these growth regulating fungicides.

Triazole and strobilurin fungicides together are used against lodging and improvement of seed yield in cereals, but little information exist for the use of these fungicides in oil seed crops. Most of the work, in this respect, is executed in green house but performance of a very few of these are studied under field conditions, the ultimate medium for production. Effect of combined application of triazole and strobilurin on quality parameters of winter rapeseed in Germany needs to be studied, as no literature in this area of research is available. Optimum level of fertilization is also main factor driving the performance of these growth regulating fungicides. Keeping in view all these points field experiments were planned to clarify the effect of triazole and strobilurin fungicides on seed yield and grain quality of winter rapeseed.

This study was therefore, conducted with the following hypotheses:

- Triazoles and strobilurins enhance seed yield by modifying the physiological attributes of winter rapeseed.
- Fungicides and growth regulator improve the yield by preventing lodging and changing the morphological traits of rapeseed.
- Triazoles and strobilurins fungicides influence the seed quality parameters of rapeseed.

2. REVIEW OF LITERATURE

2.1 Rapeseed Crop

2.1.1 Origin and history

Brassica oilseeds have been grown by humans for thousands of years and are one of the few edible oilseeds capable of being grown in cool temperate climates. They are closely related to the condiment mustards used for flavoring and for their reputed medicinal properties. There are indications that a vegetable crucifer was widely cultivated as early as 10,000 years ago. In India records have been identified which suggest that oilseed *Brassicas* (probably *B. rapa*) were being used as early as 4000 BC, and 2000 years ago their use had spread into China and Japan (Parkash 1980, Li 1980). Rapeseed was known in Europe at the time of Romans. Around the 13th century, it was used for oil purpose in northern Europe (Booth and Gunstone 2004). Rapeseed was the major source of lamp oil in Europe, by the 16th century, although it was not until the 18th century that significant cultivation areas of the crop were recorded (Kimber and McGregor 1995, Kroll 1994).

Oil from early rapeseed varieties contained a high quantity of erucic aicd (*cis* 13-docosenoic acid, 22:1n-9), which in high doses can lead to cardiac damage and related health problems. Erucic acid has bitter taste, meaning that the oil was generally used only by the poor as food oil. In time of poverty and crisis, of course, such negative aspects tended to be out weighed by necessity hence rapeseed production peaked significantly during the wars in Europe in the 20th century, particularly in World War II when rapeseed oil was used especially for the production of margarine. The rapeseed meal left after oil extraction is useful as a high protein animal feed. Quantities which can be fed are however limited, primarily due to the presence of sulfur-bearing compounds known as glucosinolates. High intakes cause problems of palatability due to the hot mustard-like taste of the glucosinolate by products and can be associated with goitrogenic, liver and kidney abnormalities and fertility problems of livestock.

The poor reputation of rapeseed oil as a foodstuff was overcome only by the development of “0” and “00” rapeseed varieties in the 1970s (Stefansson 1983, Downey et al. 1989). The first breakthrough came with the initial 0 quality cultivars with erucic acid levels of less than 1% (Stefansson 1964). Earlier rapeseed cultivars contained up to 50% erucic acid in the seed oil. The first erucic acid free variety, derived from a spontaneous mutant of the German spring rapeseed cultivar “Liho” was released in Canada in the early 1970s. The value of the crop was still suppressed by the presence in the seed of high quantities of glucosinolates, however, which made rapeseed meal unsuitable as a livestock feed. In 1969 the polish spring rape variety “Bronowski” was identified as a low gulcosinolate form and this cultivar provided the basis for an international backcrossing program to introduce this polgenic trait in to high yielding erucic acid free material. The result was the release in 1974 of the first 00 quality spring rapeseed variety, “Tower” which had zero erucic acid and low glucolsinolate content and then began the advance of rapeseed (canola) in the following decades to one of the most important oil crops in temperate areas (Snowdon et al. 2006). The canola trade mark is held by the Canola Council in Canada and may be permitted for use to describe rapeseed with less than 2% erucic acid in the oil and less than 30 mmol/g glucosinolates in the meal.

2.1.2 Botany

Rapeseed (*Brassica napus* L. genome AACC, 2n=38) is the most widely cultivated crop species in the crucifer family (*Brassicaceae*). The species is divided into two subspecies, comprising the swedes (*B. napus* spp. napobrassica) and the other is *Brassica napus* ssp. *napus*, which includes winter and spring oilseed, fodder and vegetable rape forms (Snowdon et al. 2006). The species originated through spontaneous interspecific hybridization between turnip rape (*Brassica rapa* L. syn. *Campestris* genome AA, 2n=20) and cabbage (*Brassica oleracea* L. genome CC, 2n=18), resulting in an amphidiploids genome comprising the full chromosomes complements of its two progenitors (Röbbelen 1960). There is no wild *Brassica napus,* hence it is assumed that in the mediterranean region where both of its two parental species concurred. Doubling of chromosomes in crosses among closely related *Brassica* diploid species is well documented, the related amphidiploids indian or brown mustard (*Brassica juncea* genome AABB, 2n=36) and Ethopian mustard *Brassica carinata* genome BBCC, 2n=34) arose in the same manner after crosses of black mustard (*Brassica nigra*, genome BB, 2n=16) with *Brassica rapa* and *Brassica oleracea*, respectively (Olsson et al. 1980, Downey et al. 1975).

In Europe and Asia, oilseed rape is cultivated as winter rapeseed, while in Canada, northern Europe and Australia only spring forms are suitable. Winter forms demand vernalization to promote the onset of flowering. Spring oilseed rape does not require vernalization and is not winter hardy. Winter oilseed rape is sown in autumn and survives the winter in a leaf rosette form on the soil surface. Rapeseed plants are relatively tall, ranging from 120 to 180 cm, and have a long and slender taproot. Plant stems are branched, with each branch terminating in an elongated spike. Flowers are mainly yellow with four distinct sepals and petals, six stamens and one carpel. The inflorescence is racemose, with indeterminate flowering beginning at the lowest bud on the main raceme. The leaves of the rapeseed plant are dark green, pinnate on the lower and lanceolate, sessile and clasping the stem (Snowdon et al. 2006). *Brassica napus* is a facultative out crossing species with a high degree of self pollination. When insect pollinators are abundant a greater proportion of cross-pollination can occur.

Phenological growth stages and BBCH identification keys of rapeseed were described by Weber and Bleiholder 1990 as well as Lankashire et al. 1991). Growth stages of winter rapeseed are given number from 0 to 99. Germination and Leaf development stages started BBCH 0 to 19. Formation of side shoots started from BBCH 20 and ends at BBCH 29. Stem elongation started in the spring season. In this stage visibly 9 or more internodes were developed at BBCH 39. Stem elongation was followed by inflorescence emergence which ends when individual flower buds visible but still closed. Flowering is started at BBCH 60 and ends with the completion of flowering at BBCH 69. Development of fruit lies among BBCH 71 to 79 and during which all healthy flowers develops into green pods. Ripening is the conversion of green pods to dark brown. At BBCH 89 all pods are ripe and seeds become dark and hard. After that rapeseed plant is ready for harvesting from BBCH 95 to 99. Growth stages of winter rapeseed are illustrated in Fig. 1.

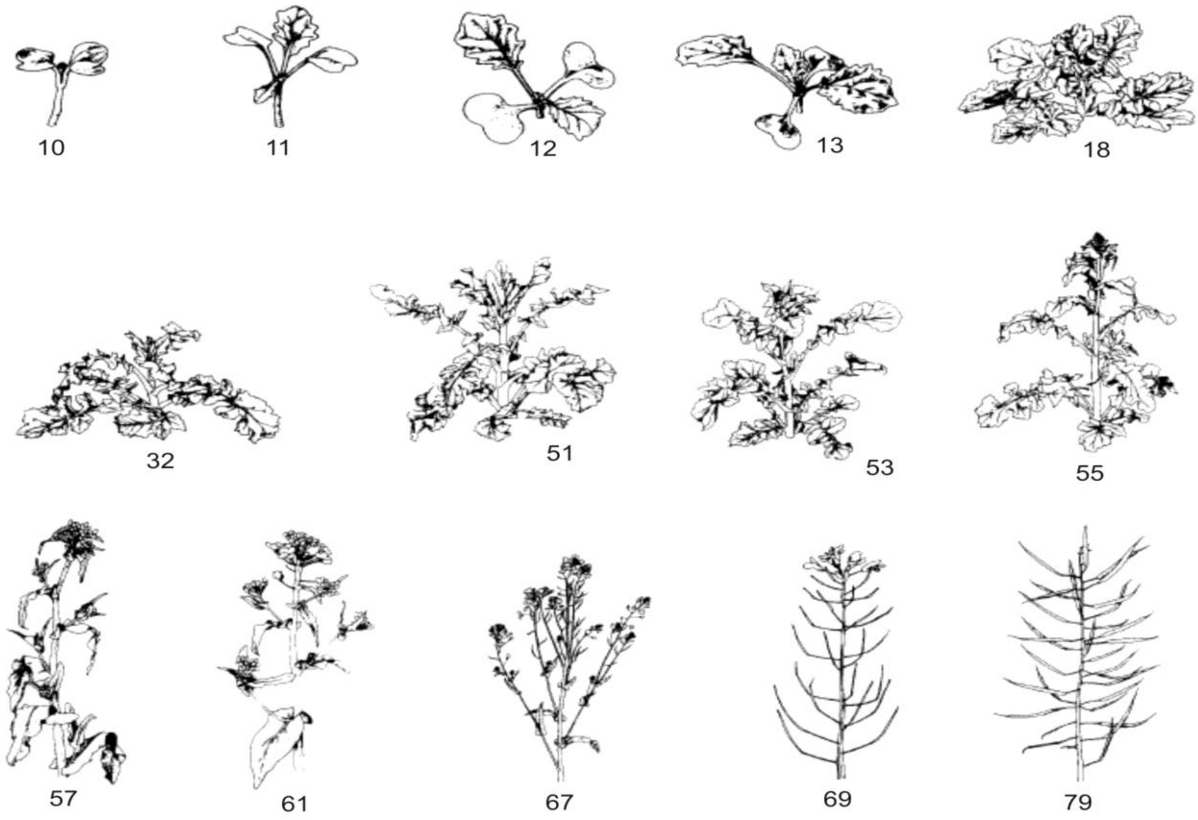


Figure 1: Growth stages of rapeseed (Weber and Bleiholder 1990)

2.1.3 Agronomy

Crop establishment

Agronomic practices vary from country to country along with species, variety, and prevailing market conditions, but, common principles which are outlined here. Rapeseed gives maximum yield on well textured and well drained soil. Rapeseed can tolerate wide range of soil pH levels ranging from 5.5 to 8.0, enabling cultivation on slightly more acidic soil than other crops. Seed bed preparation is important. Conditions that promote rapid germination and early, uniform stands and growth are important for weed control, winter hardiness and yield. Once seed has imbibed water, soil temperature is the main factor affecting speed of germination and proportion of seeds producing viable plants (Torabi et al. 2008, Hemmat 2009).

Variety selection is important for producing a rapeseed crop that contains desirable performance traits and also quality seed. Other characteristics to choose in rapeseed variety are high yield potential, winter hardiness, disease and lodging resistant (Fathy et al. 2009). Optimum date of sowing varies according to the latitude and the date of onset of winter. In Germany, winter varieties of rapeseed were sown in the latter half of August, whereas in the south of Europe, sowing date can be extended until early September. The aim in all cases is to produce plants that are sufficiently large to withstand the rigors of winter through either direct frost kill or frost heave (Taylor and Smith 1992, Gusta et al. 2004). The most common planting method is with a drill. The broadcast method can also be used to save time reduce machinery requirements but stand reliability is sometime reduced using this method. Drilling is the most reliable and preferred method. However, proper drill calibration and settings are required with this method to do a good job of seeding. Since seeds of rapeseed are small (Khan et al. 2000). Hence careful placement is required at a relatively shallow depth. The ideal seedling depth is 2-3 cm in a firm seed bed. Deeper depths delay emergence, reduce seedling vigor and delay fall growth and development. Seed rate will vary according to the date of sowing, method of crop establishment, variety, soil fertility and method of harvesting. Plant population for modern varieties can be reduced slightly due to expected higher vigor, but as seed size tends to be larger, this may not result in a reduction in seed rate per hectare (Lääniste et al. 2008). The recommended plant population is 40-50 plants/m^2 for many varieties in Germany. The 15-22 cm row spacing provided by most of commercial grain drill is acceptable for winter rapeseed production (Shahin and Valiollah 2009).

Fertilization

Nitrogen

The nitrogen supply of rapeseed is of central importance to ensure high yields. Nitrogen is an integral component of nucleic and amino acids, nucleotides, protein, chromosomes, genes, ribosome, chlorophyll and also a constituent of all enzymes. The wide range of different N-containing compounds explains the important role of nitrogen for rapeseed. As a major nutrient, nitrogen has not only a considerable influence on seed yield formation but also on seed quality of rapeseed. Nitrogen application increases the concentration of protein with a decrease of the oil content (Brennan 2000). Nitrogen deficiency in an early stage of rapeseed development inhibits vegetative growth, reduces productivity through lower leaf area index and shortens the period of photosynthetic activity (Al Barak 2006). Nitrogen is mobile within the plant hence symptoms appear first in the older leaves whereas the younger part remain green for certain time. Restricted N-Nutrition reduces the number of seeds per plant and seed weight of rapeseed regardless of cultivar. Deficit supply of nitrogen not only limits yield but also the protein content of the seeds (Yasari and Patwardhan 2006). Nitrogen has control in the regulation of phytohormone. N-deficiency accelerates the production of abscisic acid which plays a role in the shortening of growth period, aging processes and the filling of assimilates in the seeds (Chraibi et al. 1995).

In winter rapeseed, nitrogen is applied in three splits. First application of nitrogen is made at the start of growth (autumn), the second at the start of shooting (spring) and the third at the late bud stage (Sauermann 2000). The application of nitrogen in autumn should be considered under all conditions under which growth is delayed before winter. The need for an application of nitrogen in autumn of up to 40-50 kg/ha N. Rate and time of autumn application depends on a number of factors (soil type, sowing time, preceding crop and weather conditions). In early sown rapeseed, decision of application can be made up to 4 leaf stage and in late sowing, nitrogen should be applied directly at sowing. In Germany, autumn application should be completed at latest by the end of September. In spring when rape pant starts new growth, then it mobilizes assimilates and nutrients from assimilate reserve stored in leaves and stems in autumn, to produce a well developed a root system side branches and enough leaves (Harris 1980). Number of lateral branches is considered a fundamental yield characteristic influencing the number of leaves which can be constituted before the onset of shooting. For this reason, the most important aim of all inputs in spring should be to develop an adequate number of lateral branches in the rape plants. Rate of nitrogen in spring depends on several factors in which most important are yield potential, mineral N in the soil, soil organic matter, plant development before winter, site condition, N rate in autumn and leaf loss during winter period. In Germany, the N fertilizer rate is based on the N demand of the crop and the nitrate content of the soil (0-90cm) measured by soil analysis (Orlovius 2003). During spring in Hessen state of Germany, recommended rate of N fertilizer is 100 to 120 kg/ha. At flowering stage about 90 to 100 kg/ha N must be applied. Fewer pods are produced if the requirement of these amounts of N cannot be met due to insufficient N supply an inadequate translocation.

The temporary and very intensive uptake of rape plant demands high availability and predictable effect of the applied N fertilizer. N fertilizers used worldwide are ammonium nitrate and Urea, seems to be rather similar on rapeseed (Bybordi and Gheibi 2009). When nitrogen is applied in the form of ammonium nitrate then the demand of plant for nitrate is also satisfied. From early application and under unfavourable weather conditions (dry, hot, windy) considerable gaseous N-loss from urea has to be taken into account (Li et al. 2009). In some European countries, a liquid nitrogen form of ammonium nitrate urea solution is also commonly used by using sprayer for receiving quick response of nitrogen (Heinkel 2009). The use of ammonium sulphate has the advantage of providing both nutrients nitrogen and sulphate in the one fertilizer.

Sulphur

In rape plant, sulphur plays an indispensable role in rape plant metabolism as a component of proteins and glucosinolates. It is taken up by the roots as sulphate and transported via the xylem to the leaves where sulphur is reduced to cysteine and either converted to methionine or incorporated in to proteins and cysteine containing peptides such as glutathione. Sulphur not only controls the amount of protein but also it influences the quality of protein (Wrigley et al. 1980). In green leaves most of the protein is located in the chloroplasts. Hence it is not surprising that under insufficient S supply the chlorophyll content decreases and the green color of leaves becomes lighter and changes to yellow because of chloroplast damage and reducing chlorophyll content (Bergmann 1992). Sulphur increases the concentration of essential unsaturated fatty acids in oil and enhances the usability of rapeseed oil. The Sulphur containing amino acids are also precursors of other compounds such as coenzymes and secondary plant products. Glucosinolates are secondary S-containing plant products of *Brassica* species affecting plant resistance to disease and pests. Glucosinolates are considered resistance barriers to the plant which contribute to a general plant defense mechanism (Schlösser 1983). On the other hand a high content of glucosinolates impairs the quality of oil and meal. Because of the increasing effect of excessive sulphur nutrition on the content of glucosinolate, Sulphur fertilization must be optimized to obtain high yields of good quality. Low sulphur supply impairs the quality of rapeseed because the oil content decreases.

First deficiency symptom of sulphur appear on the youngest leaves of the plant which show spoon like deformation, often together with a reddish discoloration because of the enrichment of anthocyanins. The onset of flowering is delayed and the color of the petals changes from bright yellow to pale yellow and under severe S-deficiency conditions to white petals. Additionally the petals are smaller. The flowering period is particularly critical for yield formation because the fertility of flowers is reduced under S-deficiency (Haneklaus et al. 2005). Even at this late stage of development it is possible to correct S-status by foliar fertilization and it is highly effective (Podleśna 2005). With sulphur deficiency number and size of pods and seeds per pod also reduced. In Germany, sulphur is applied at the rate of 70-100 kg/ha mostly by using ammonium sulphate.

Because of the central role of sulphur and nitrogen in the production of proteins there is a close relationship between the supplies of S and N in plants. For many different crops and also for oilseed rape, it has been shown that high rates of nitrogen create sulphur deficiency if the sulphur nutrition is not adequate to meet the higher N supply (Blake-Kalff et al. 1998). On the other hand, the efficiency of nitrogen fertilization is improved through an adequate supply of sulphur.

Crop protection

Weeds

Weeds within the oilseed rape crop can cause a number of significant problems which are responsible for considerable growing costs. Oilseed rape is a slow-growing crop. Consequently, rapeseed is very sensitive to weed competition, especially during early stages of development. Weeds cause direct yield losses through competition for light, nutrients and space. In rotation with cereals, volunteer plants from the previous cereal crops are particularly competitive. Weeds can also interfere with harvesting. Weeds that germinate in autumn are the main problem in winter oilseed rape as the crop is planted during that time. Some weeds such as chickweed, cleaves and speedwells grow at lower temperatures and threaten to smother the oilseed rape crop in early spring (Davies 2005). In general, weeds in the winter oilseed rape fields of Europe are volunteer cereal grasses and botanically similar, closely related brassica weeds which include Chalock, Wild mustard, Stinkweed, ball mustard, wormseed mustard and shepherd’s purse. Overall, of the weeds that infest winter oilseed rape in the Germany are black grass, chick weed, mayweeds, red deadnettle, forget-me-not, field pansy, and annual meadow grass.

In some parts of the world weeds are controlled through cultural means alone, while in Europe control of weeds is frequently achieved by combination of agronomic practices and use of herbicides. Cultural practices include rotation, time of sowing, inversion tillage, between crop management, hand and mechanical weeding and stale seed beds.

Diseases

There are numerous diseases of rapeseed that may cause production losses to a greater or lesser extent in different areas of the world. Sclerotinia stem rot (*Sclerotinia sclerotiorum*) and stem canker (*Leptoshaeria maculans*), also known as black leg, are the major diseases of rapeseed (Rimmer and Buckwaldt 1995). *Veticillium wilt* is a common disease in Germany and Sweden. Light leaf spot (*Pyrenopeziza brassicae*) in northern parts of Europe and Clubroot (*Plasmodiophora brassica*e) is considered major disease in Scandinavian countries. Sclerotinia stem rot is the most important disease of rapeseed in China and also a major cause of yield loss in Germany and France (Krüger and Stolten-berg 1983, Liu et al. 1990).

Control of disease has involved a range of strategies. Black leg and light leaf spot are most effectively controlled by the use of resistant cultivars through other management practices are also useful in supplementing resistance (Long et al. 2011). Cultural control methods, particularly rotation, are important means of controlling diseases such as sclerotinia and clubroot. Optimum agronomic practices will limit the number of susceptible crops in the rotation. Use of fungicides may also be part of the control of Brassica diseases. Seed treatment and foliar application of fungicides are both routinely used for the control of different disease of rapeseed (Bradly et al. 2006).

Insects

A wide range of insect species attacks on rapeseed which affects the crop at establishment, during growth and harvest time. During growth a range of insects may occur. Cabbage-stem flea beetle (*Psylliodes chrysocephala*) is one of the important insects on winter rape seed in Europe (Ekbom 1995). Several species of aphid can also cause damage. *Myzus persicae* can also act as a virus vector for beet western yellow virus especially in the autumn. Flea beetles (*Phyllotreta* spp) are considered very adverse insects for spring rapeseed. Slugs can also cause a significant damage at early leaf stage and are associated with wet and heavy soils. Pollen beetles (*Meligethes spp*) are the most significant insects of rapeseed in Scandinavia and Scotland (Nilsson 1987). Seed weevil (*Ceuthorhynchus assimilis*) and pod midge (*Dasinaura brassicae*) are common insects of rapeseed in Europe and North America. Both species of insects lay eggs into the pods, the larvae feed on the developing seeds.

Insecticides are applied to control the most important pests of rapeseed (Butani 1974, Nilsson 1987). Conservation biological control to enhance natural control appears the most feasible approach to solve the problem (Hokkanen 2008). Cultural control practices such as crop rotation, adjustment to seedling date and cultivation practice are effective for controlling. Better knowledge of factors stimulating insects is developing and this should enable more targeted plant breeding in the future.

2.1.4 Quality characteristics of rapeseed

Oil content

Oil acts as a vehicle for some of the important vitamins and also plays a significant role in metabolic functions. Therefore, oil is an integral part of our diet, providing most concentrated form of energy. The quality of rapeseed, to a large extent, is dependent on the oil content that shows the economic value of the crop. The oil content for Brassica oilseeds ranges from 35 to 50% (Downey and Rimmer, 1993). It is possible to develop cultivars with increased oil content however, it results at the expense of reduction in either carbohydrate or proteins accumulation. The energy expense for increased oil accumulation is greater if the oil content is enhanced by a decrease in the carbohydrates compared with protein (Mitra and Bhatia 1979). Bhatia and Mitra (1992) have proposed that an increase of 5% in oil content, as a result of carbohydrate reduction in the seed, enhances the photosynthetic requirement by 4.6%, while a similar increase in oil as a result of reduced protein accumulation results in 1.8% increase in photosynthetic requirement. A negative correlation has been shown to exist between seed oil and protein or carbohydrate content in rapeseed (Grami et al. 1977).

Fatty acid profile

Rapeseed oil is composed of more than 90% of triglycerides that contain one glycerol molecule linked by covalent bonds to three fatty acid molecules. The physical and chemical properties of rapeseed oil are directly dependent on the composition of fatty acids that make up the triglycerides and the occurrence of double bonds between the carbon molecules that make up the fatty acids.

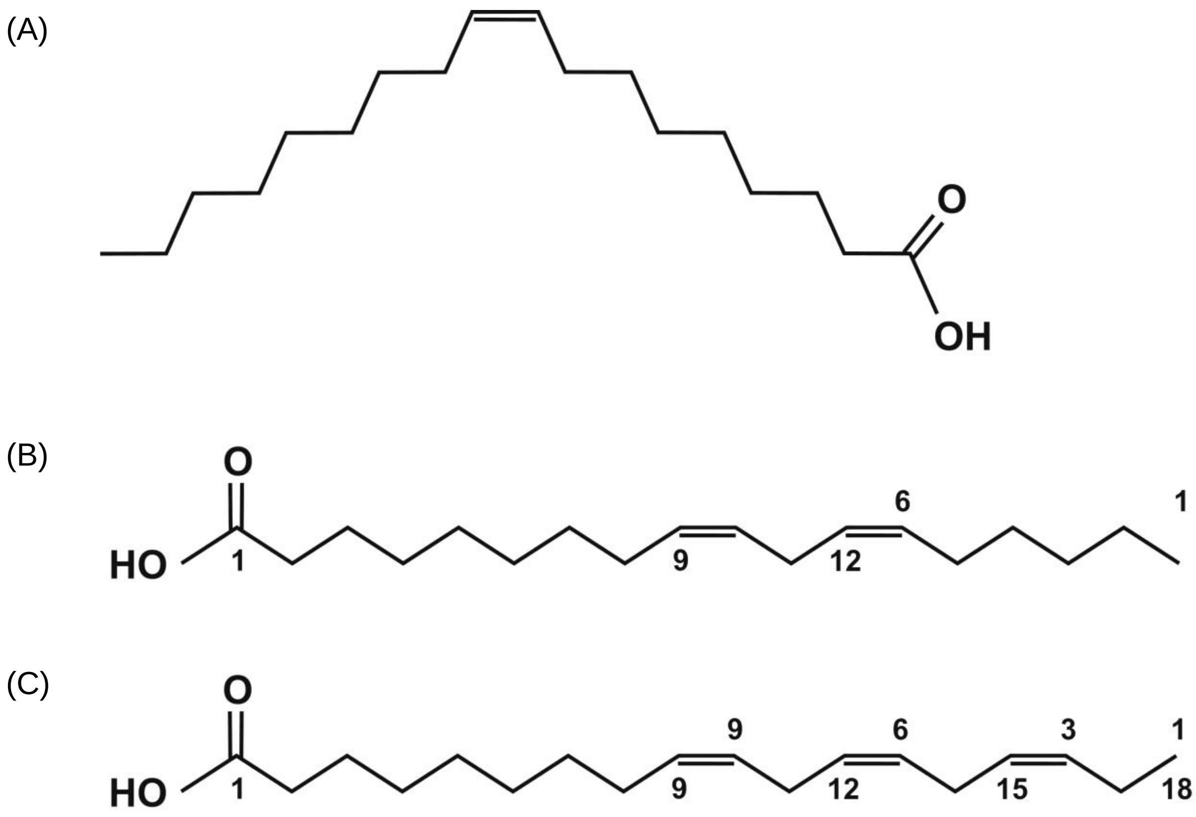


Figure 2: Chemical structures of oleic (A), linoleic (B) and linolenic acid (C) (Aydin 2005, Scrimgeour 2005)

On the basis of occurrence of the double bond, fatty acids can be classified as saturated fatty acids, monounsaturated and polyunsaturated fatty acids. The saturated fatty acids (palmitic acid C16:0 and stearic acid C18:0) increase the levels of low density lipoprotein (LDL) in the blood that has a significant role in cholesterol deposition, and are thus undesired for human nutrition (Gurr 1992). The monounsaturated fatty acid (oleic acid C18:1) being thermo stable provides a longer shelf life and are preferred for cooking and deep frying (Prabhu 2000). It also reduces cholesterol and is thus beneficial for health (Bonanone et al. 1992). The rapeseed oil provides two essential polyunsaturated fatty acids, linoleic and linolenic (C18:2 and C18:3, respectively), that need to be supplemented in the diet (Newton 1998) and are not present in most of the other edible oils such as sunflower and groundnut (Prakash et al. 2000).

Long chain unsaturated fatty acid erucic acid (C22:1) containing oil is nutritionally undesired and efforts have been directed towards development of rapeseed cultivars having oil free of or with low levels of erucic acid along with high levels of oleic, moderate amounts of linoleic and low levels of linolenic acids (Downey and Rimmer, 1993). Rapeseed oil having less than 2% erucic acid about 4-6% saturated fatty acids, 60- 65% oleic, 20% linoleic and 9% linolenic acid, and is considered as having the ideal fatty acid composition of edible oils that is preferred internationally for human consumption (Downey 1990).

Free fatty acids

The acidity in rape oil is the result of breakdown of the triacylglycerols due to a chemical reaction called hydrolysis or lipolysis, in which free fatty acids are formed (Fig. 3).

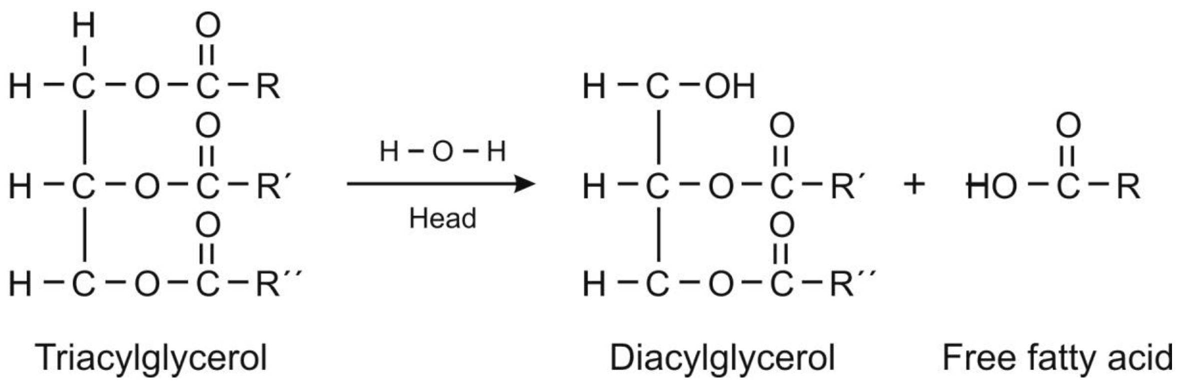


Figure 3: Hydrolysis of oil (List et al. 2005)

Presence of free fatty acids (FFA) in the oil of rapeseed more than threshold level (0.5%) is considered undesirable for human consumption as well as for industrial purposes (Canakci and Van Gerpen 2001). Oil extracted carelessly and from poor quality seed suffers from a very significant breakdown of the triacylglycerides into fatty acids. These broken off fatty acids are called free fatty acids. Sometimes just one of the three fatty acids breaks off, leaving a diacylglycerol. If two fatty acids break off, we are left with a monoacylglycerol. If all three break off, are left with glycerol. Factors which lead to high concentration of free fatty acid in rape oil delays between harvesting and extraction (especially if the seeds has been bruised or damaged during harvesting), fungal diseases in the seeds (McCarty et al. 1999), prolonged contact between oil and vegetation water (after extraction), and careless extraction methods (May et al. 1989).

Protein content

The rapeseed meal by product of oil extraction contains between 36 to 44% proteins which is valuable animal feed (Miller et al. 1962). Rapeseed protein is a very good complete protein and worth of development which has great value of utilization. It is rich in sulphur containing amino acids lysine, methionine and cystine which are limiting in cereals (Chadd et al. 2002). Rapeseed also contains substantial amount of threonine. Although some variation in the protein content of rapeseed can be due to cultivar, soil type and environmental factors (Bell 1995).

Peroxides value

Peroxide value (PV) is the measure of the primary lipid oxidation indicating the amount of peroxides formed in oil during oxidation (Ozkan et al. 2007, List et al. 2005). It has been postulated that the double bond within a fatty acid molecule capable of capturing outside source of energy, such as heat and light, to reach a critical excitation level (Howard and Leonard 1982).

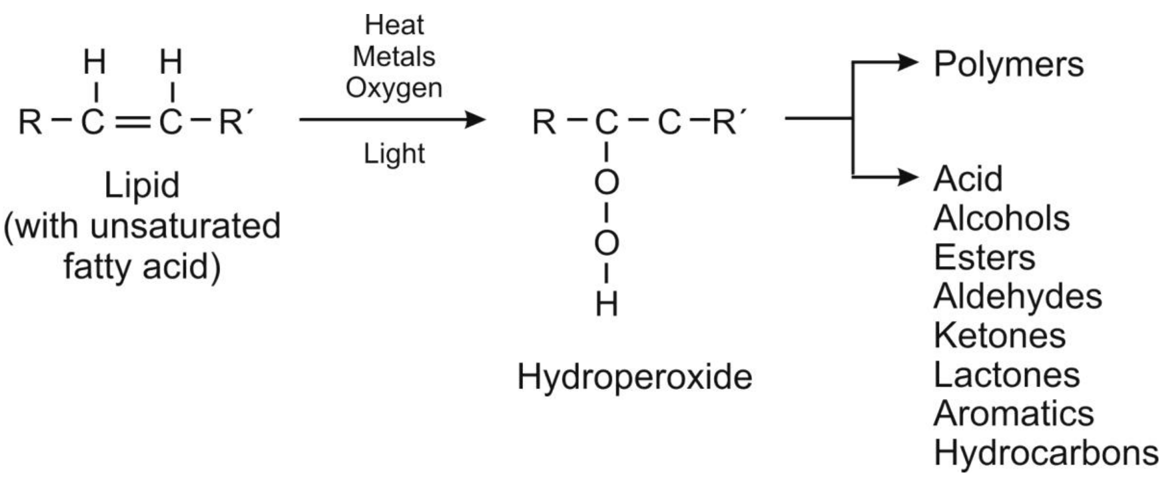


Figure 4: Oxidation of oil and its possible oxidizing products (List et al. 2005)

Major reason of this oxidation is the presence of sufficient concentration of polyunsaturated fatty acids (linoleic and linolenic acid) in the rape oil (Fig. 4). The polyunsaturated fatty acids in rape oil determine its nutritional value but they also cause of its instability. Monounsaturated fatty acids, since they have a pair of missing hydrogen atoms are somewhat vulnerable to oxidation. Polyunsaturated oils, which are missing several pairs of hydrogen atoms are very unstable and highly reactive to oxidation. The oxidation of fatty acids changes the chemical properties of the rape oil it reduces the nutritional value of the fat, darkens its color and can cause off flavor.

2.1.5 Uses of rapeseed

Uses of rape oil

In human nutrition rape oil is preferable to animal fats because of their lower contents of cholesterol and their generally high proportions of unsaturated fatty acids of which linoleic acid and linolenic acid are most important (Beringer 1977). The rape oil of today is thus valuable plant oil for human nutrition with an exquisite flavor. Comparisons of margarines produced from rapeseed oil and sunflower oil have shown no difference in flavor. In most of cases rapeseed oil has been shown to be superior to other dietary oils for frying and cooking (Gustafson et al. 1993).

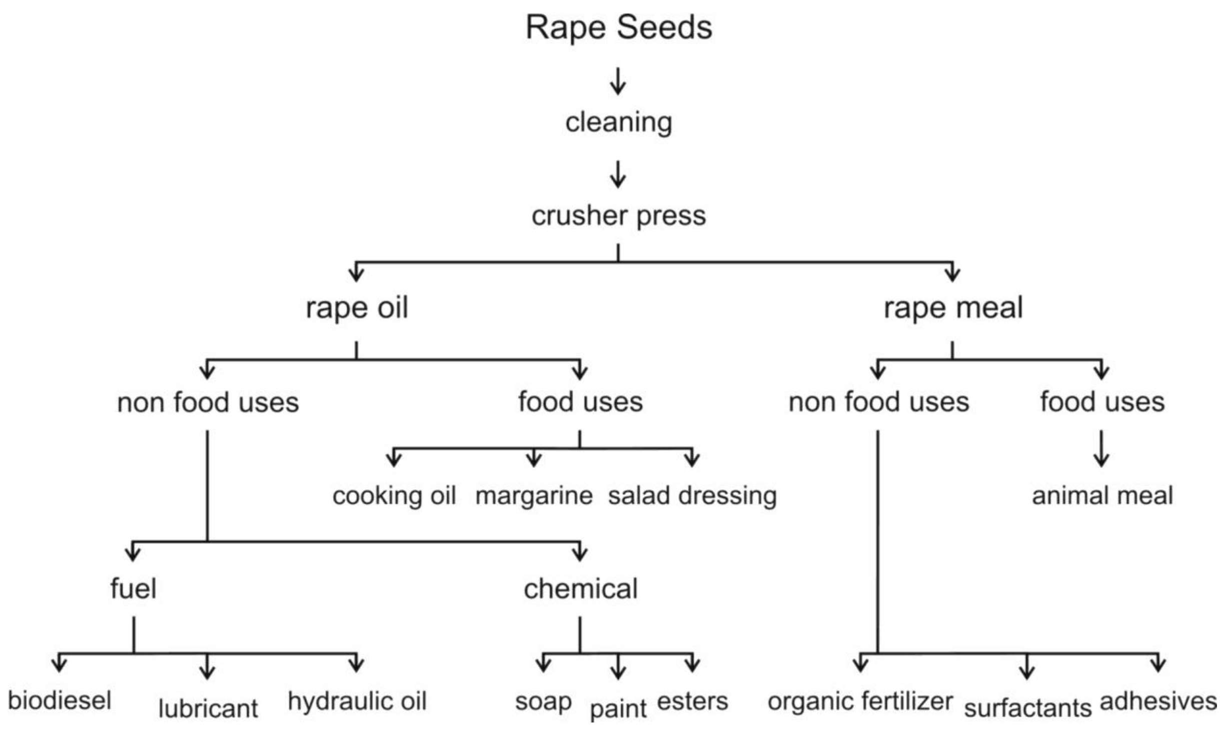


Figure 5: Uses of rapeseed

Beside the advantageous composition of fatty acids of rapeseed oil, the adequate concentration of vitamin E and other plant sterols makes this oil type of valuable quality for human nutrition. Rape oil is used not only as nutritious cooking oil but also as an important source for the production of other foodstuffs (such as margarine, salad dressings, mayonnaise, baby food) and frying fat for cooking. In the last decade, rape oil has been introduced as a raw material able to be used for diverse purposes outside the nutritional sector. A wide range of direct and indirect possible uses of rape oil has been developed. There are two main directions of development have occurred: use of rape oil as a source for regenerative energy (bio-energy) and the direct use of the oil for technical purposes relating to its environmental friendly behavior and special chemical composition. In the chemical industry rape oil is a raw material for producing special chemicals such as glycerin, amines, esters, soaps, paints, vanishes and lacquers. Industrial uses of rape oil in environmentally sensitive areas include bio-diesel, hydraulic oil and lubricating oil. Using “bio-diesel”, it is possible to replace diesel from mineral oil totally without necessary modification of the motor. “Bio-diesel” can be rapidly decomposed biologically and in environmentally sensitive areas it should especially be used, as for example for all vehicles in water and nature reserves (Strong et al. 2004). “Bio-diesel” is virtual free of sulphur. For this reason the exhaust fumes are also free of sulphur oxides so that there is no leakage of these oxides into the atmosphere to cause acid rain (Orlovius 2001).

Uses of rape meal

The high source of energy and crude protein is the decisive factor determining the use of rape meal in animal nutrition. Its high content of crude protein in relation to its market price makes rape meal a popular and widespread protein supplement in animal feed. In the past the part played by rape meal in animal food rations was limited because of unwanted substances especially erucic acid and glucosinolates. The protein composition of rape meal is favorable for animal nutrition. The amino acid composition of the protein essential amino acid content of rape meal is of generally good nutritional quality. The higher content of essential amino acids i.e. mthionine, cystine and threonine of rape meal decisively determines the quality of the protein. (Orlovius 2001). A major advantage is the very high content of selenium, ash and minerals, in rape meal generally exceeds that of soybean meal (Lebzien 1991). Rape meal has many non food uses. In China, It is used as organic fertilizer. It is also used in the production of adhesives and surfactants.

2.2 Triazoles

2.2.1 Introduction

In 1960, several compounds from the chemical class of 1-substituted imidazoles and 1, 2, 4-triazoles were commercially developed and successfully used for the treatment of plant (Fig. 6). Triazole fungicides include the most active compounds known today for controlling plant diseases. The azole fungicides belong to the large group of ergosterol biosynthesis inhibitors that interfere with the biosynthesis of fungal steroids. Certain triazole compounds interfere with the biosynthesis of gibberellins and influence the morphogenesis of plants, indicating their possible use as plant growth regulators. Hence, several azole derivatives were developed and recommended for use worldwide as either fungicides or plant growth regulators. Triazole is the largest group and most important group of systemic compounds use for controlling of disease in plants and animals (Siegel 1981). Triazole compounds have both fungitoxic and plant growth regulating properties and they are considered much more effective than many other plant growth regulators, generally requiring low rates of applications (Davies et al. 1988, Fletcher et al. 1986).

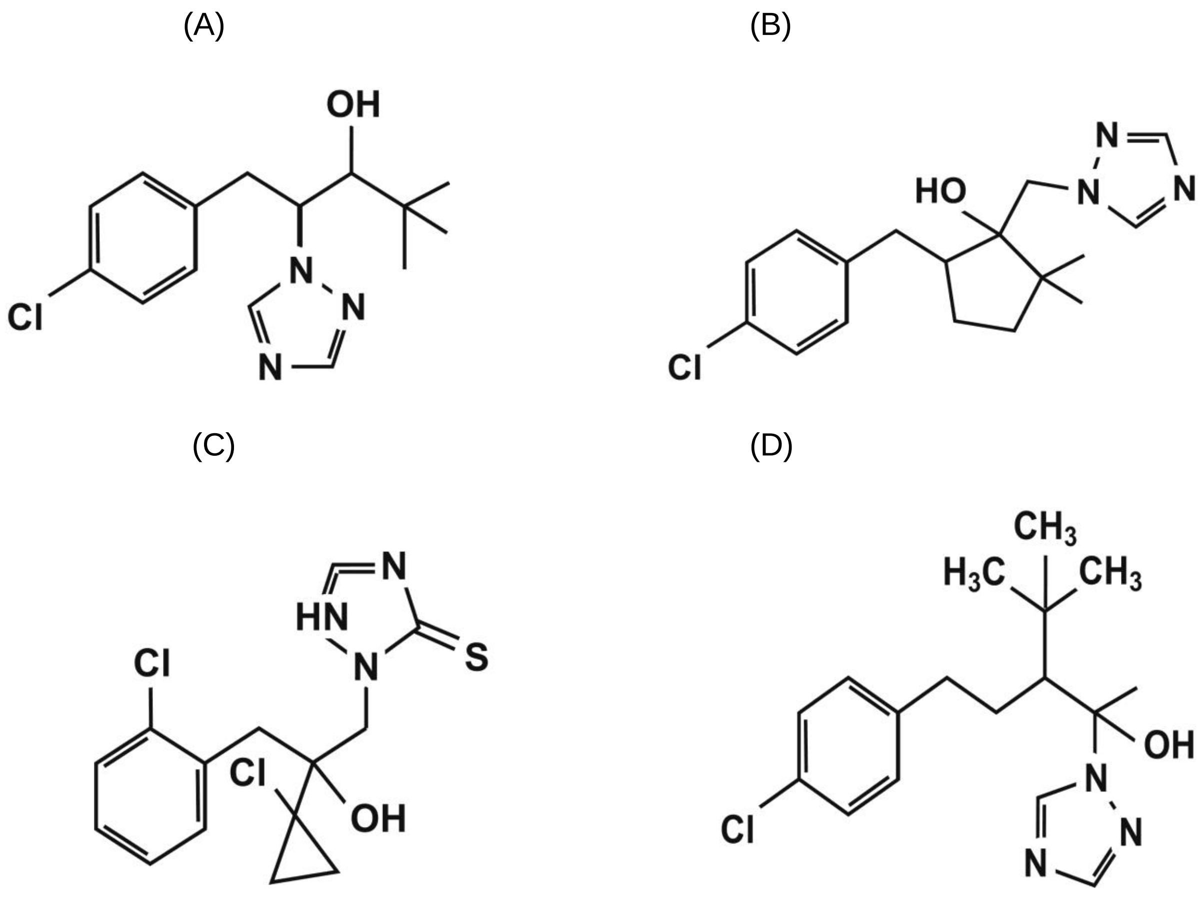


Figure 6: Chemical structures of paclobutrazole (A), metconazole (B), prothioconazole (C) and tebuconazole (D) (Rademacher 2000)

2.2.2 Physiological and biochemical responses to triazoles

Gibberellin anabolism and ABA catabolism

The primary action of triazoles type growth regulators (Fig. 7) consists of lowering plant content of gibberellins through inhibition of gibberellins biosynthesis (Rademacher 2000).

Generally, metabolism of terpenoids, from which the phytohormone groups of gibberellins, abscisic acid (ABA), and cytokinins are derived, involves main target sites for the growth regulator attack (Grossman 1990). Triazoles inhibit monooxygenases, which oxidize in three steps *ent*-kaurene to *ent*-kaurenoic acid, an early reaction in gibberellins biosynthesis (Hedden and Kamiya 1997, Rademacher 2000).

Azole compunds inhibit the cytochrome P450-dependent 8-hydroxylation of ABA, which is required for ABA conversion into phaseic acid (Fletcher et al. 2000 and Rademacher 2000). Lowering indole-3-acetic acid (IAA) levels in triazole treated plants could be a side effect of GA inhibition, since GA induces IAA biosynthesis (Porlingis and Koukourikou-Petridou 1996).

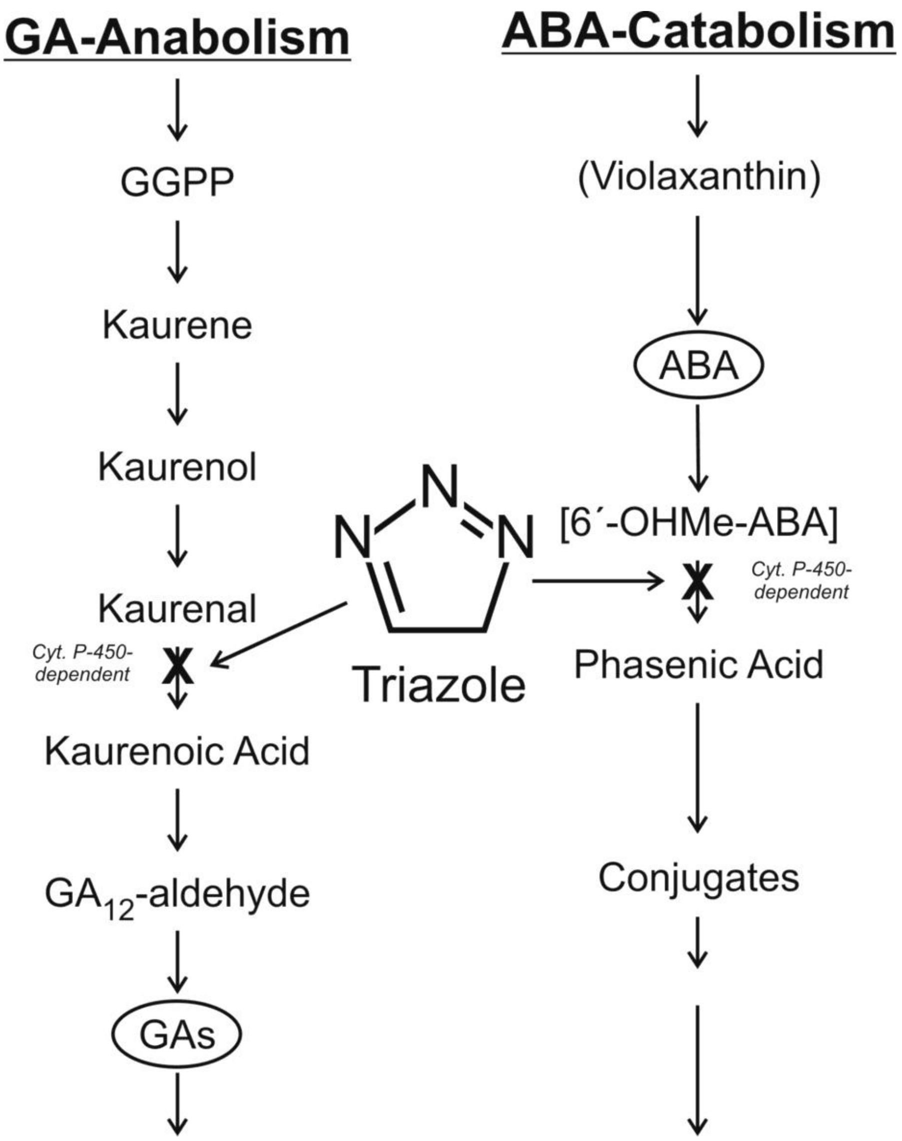


Figure 7: Proposed involvement of triazoles in GA and ABA metabolism (Rademacher 2000)

Sterol biosynthesis

Triazoles are structurally related to a number of sterol biosynthesis inhibitors which have been used extensively in both agriculture and medicine. Triazoles inhibit biosynthesis of sterols in plants and fungi by blocking oxidative 14 α-demethylation reactions in the course of sterol biosynthesis (Fletcher et al. 2000, Rademacher 2000). Biosynthesis of sterols is an important process for cell division suggesting that its inhibition represents another mechanism of growth retardation in triazole-treated plants (Asami and Yoshida 1999). Hence, it has been suggested that the inhibition of sterol biosynthesis may play significant role in the growth regulating activity of a number of triazole compounds including paclobutrazol.

Energy metabolism

It was also suggested that triazoles treating plants contribute to inefficient energy metabolism (Bai and Chaney 2001). Paclobutrazol and flurprimidol inhibited oxidation of nicotine amide adenine dinucleotide (NADH) and reduction of cytochrome c, the first and the final steps in mitochondria electron transport chain, respectively (Bai and Chaney 2001). Oxidation of NADH is dependent on cytochrome P450 and Fe-S protein (Buchanan et al. 2000). The last one is supposedly affected by growth regulators (Bai and Chaney 2001). Triazoles might influence iron of cytochrome c oxidase in the same manner as they react with a heme moiety of cytochrome P450 (Bai and Chaney 2001). These authors speculated that lowering energy metabolism in triazole-treated plants is a height reduction mechanism, which is an alternative to GA biosynthesis inhibition (Bai and Chaney 2001).

Photosynthesis

On a leaf area basis, triazole generally has little direct effect on rates of net photosynthesis (Davis et al. 1988). It may affect photosynthesis by altering canopy structure, thereby influencing light penetration and absorption. In several plants, the leaves on azole-treated plants were retained longer than on controls and the onset of leaf senescence was also delayed considerably (Davis and curry 1991).

Leaves of triazoles treated plants are darker green than controls. This response is not unique to triazole as other growth retardants also intensify the green color of foliage (Sankla et al. 1985). It is not known however whether the increased chlorophyll content of triazole treated leaves is a result of enhanced chlorophyll synthesis or is simply a result of a concentrating effect due to a reduction in leaf area (Berova and Zlatev 2003, Fletcher et al. 2000, khalil and Hidayat-ur-Rahman 1995). Studies on the activities of enzymes of chlorophyll formation and catabolism after treatment would be worthwhile in this respect. Growth regulators reduce chlorophyll content by inhibition of cytochrome P450- dependent hydroxylation reactions in chlorophyll biosynthesis (Davis et al. 1988).

Stress tolerance and assimilate distribution

Crop plants are often subjected to environmental stresses that interfere with their normal physiological processes, affecting growth, development and ultimately crop yield. In addition to their growth regulatory and fungicidal effects, azole compounds have been found to be highly effective in protecting plants from various environmental stresses (Davis et al. 1988 and Fletcher and Hofstra 1988). In addition to fungicidal action, it was demonstrated that triazole protected plants from injury due to biotic and abiotic stresses, including diseases, drought, chilling, ozone, heat, and air pollutants. Hence, the azole fungicides are referred to as plant multi-protectants (Fletcher and Hofstra 1985). Plants treated with triazole typically use less water than untreated plants. Water use by triazole treated plants was reduced by 35% due to reduction in leaf area and stomatal conductance (Fuller and Zajicek 1995). Water potential of treated plants is generally higher than that of untreated plants. It has been suggested that triazole treated plants may be better able to withstand drought conditions (Davis et al. 1988).

Triazoles are also known to shift assimilate partitioning from leaves to roots and could also alter mineral uptake and plant nutrition (Yelenosky et al. 1995). Stimulation of root growth may be related to the increased partitioning of assimilates towards roots due to the decreased demand in the shoots (Sympsons et al. 1990, Wang et al. 1985).

2.3 Strobilurins

2.3.1 Introduction

Strobilurins are natural substances isolated mainly from mushrooms (*besidiomycetes*). Their name is derived from mushroom genera *strobilurus*. The strobilurins are a new class of systemic fungicides with a unique mode of action which targets the mitochondrial respiration by blocking the electron transport at the outer side of the cytochrome-bc_1 complex (Balba et al. 2007). For this reason farmers quickly adopted them such that 3 years after their introduction in 1996, sales of strobilurin fungicides totalled $620 million, representing 10% of the global fungicides market (Bartlett et al. 2002). Strobilurin inhibit the germination and penetration growth of several plant pathogenic fungi, while azole group of fungicides generally do not inhibit fungal growth until after initial infection (Godwin et al. 1994). In addition to these fungicidal side effects on plants has been reported which results in maximum seed yield. Several mechanisms have been discussed in which way strobilurin containing fungicides are responsible for physiological changes in crop plants. At present there are about eight synthetic strobilurin in the fungicides worldwide market. Some of these products are worldwide registered for use as agrochemical and some are in the process of registration (Balba et al. 2007).

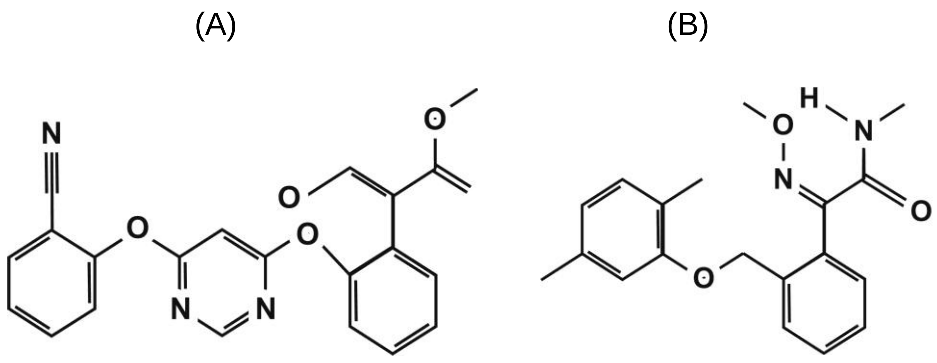


Figure 8: Chemical structures of azoxystrobin (A) and dimoxystrobin (B) (Balba et al. 2007)

2.3.2 Physiological and biochemical responses to strobilurins

Ethylene biosynthesis

The strobilurins proved to inhibit the biosynthesis of ethylene through reduction of the activity of 1-aminocyclopropane-1-carboxylic acid (ACC)-synthase (Fig. 9). This has been linked with delayed the senescence of leaves and consequently prolonged photosynthetic activity of green tissues and a better management of stress (Grossmann et al. 1999). Ethylene impairs production by promoting leaf senescence and the start of premature ripening of the grains, which reduces production of assimilates and the period of grain filling.

Nitrogen assimilation

Strobilurins application fulfills the high nitrogen demand of plant by strongly activating the effect of NADH-nitrate reductase which catalyzes the first step in nitrate assimilation (Fig. 9). The reduction of nitrate to nitrite is regarded as the rate –limiting step in N-assimilation and highly regulated (Glaab and Kaiser 1999). Strobilurins stimulate the level of nitrate reduction about 100% during the nocturnal period (Köehle et al. 2003). This enhancement in nitrate reduction persisted for 3 nights after the application of strobilurin.

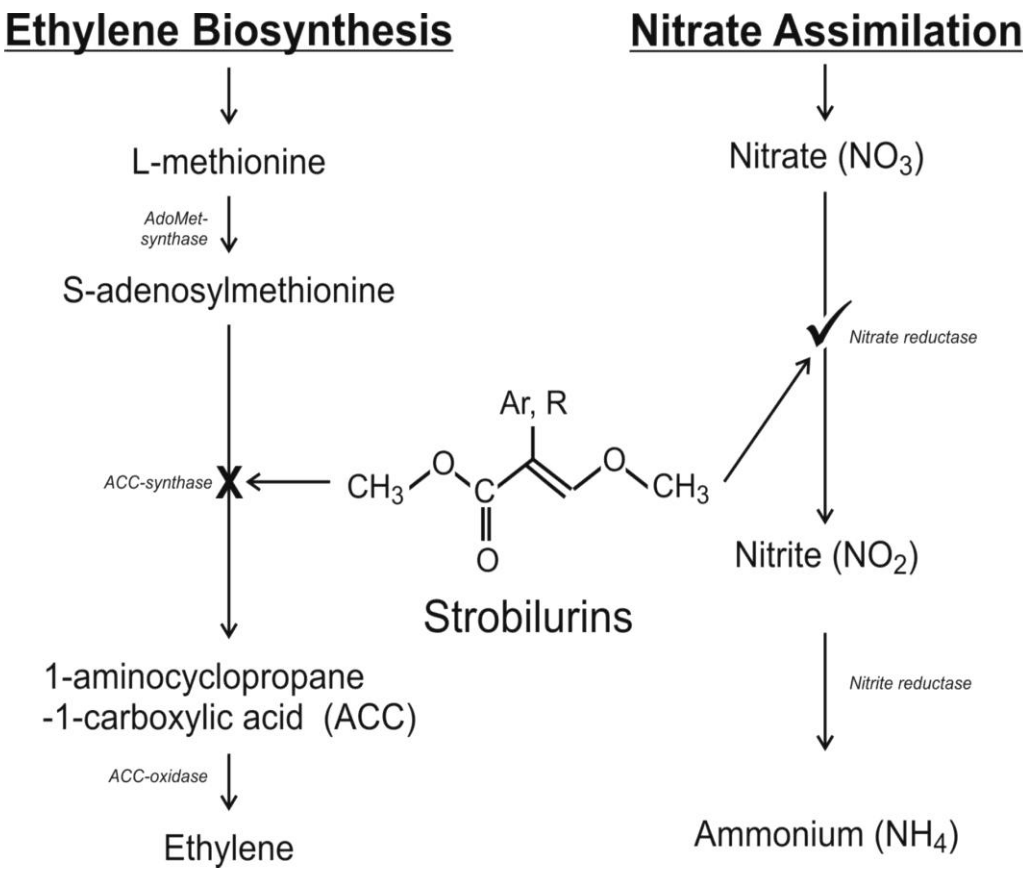


Figure 9: Proposed involvement of strobilurins in ethylene biosynthesis and nitrate assimilation (Köehle et al. 2003, Grossmann and Retzlaff 1997)

Delayed senescence

Strobilurins inhibited chlorophyll and protein loss which are parameter of senescence progression (Grossmann and Retzlaff 1997). This retardation of senescence by strobilurins had close relation with decreasing levels of formation of ACC, ethylene and increase of Indol-3-acetic acid. Strobilurin enhance the level of Auxin (Indol-3-acetic acid) in wheat plant (Köehle et al. 2003). Another important effect of strobilurin, it increases concentration endogenous levels of abscisic acid (ABA). This hormone inhibits growth and stomatic opening, especially when the plant is under environmental stress which improves the utilization of water under conditions of water stress and the adaptation to low temperatures (Grossmann et al. 1999).

Alleviation of oxidative stress

Senescence is now widely considered a process associated with and driven by active oxygen species (AOS) responsible for oxidative stress (Li et al. 2007). To counter AOS stress, plants had evolved antioxidative strategies in which antioxidant enzymes played a central role (Hadrami et al. 2005). Lipid peroxidation is considered an important symptom of leaf senescence and can be initiated by AOS. The damage of membranes caused by AOS during senescence leads to increased membrane leakiness (Trippi et al. 1989). Superoxide dismutase (SOD), Catalases (CAT) and Peroxidases (POD) are three key enzymes in the active-oxygen scavenging system that can quench active oxygen species (Zhao et al. 2007). Strobilurins increased the activity of these antioxidant enzymes and protect the plants from harmful active oxygen species (Zhang et al. 2010).

2.4. Trinexapac

2.4.1 Introduction

Growth retardants are natural or synthetic chemical substances that can be directly applied on plants to alter structural or vital processes by modifying hormone balance to increase yield, improve quality or facilitate harvesting. A growth retardant trinexapac-ethyl (Moddus) is a cyclohexandione and represents a new chemical class of plant growth regulators (Fig. 10). Studies have revealed that the cyclohexandiones inhibit post GA_{12}-aldehyde reactions leading to the biosynthesis of gibberellins. The primary reactions affected appear to be 3ß-hydroxylations, although other reactions between GA_{12}-aldehyde and GA_1 may also be inhibited (Srivastava 2002). Trinexapac-ethyl, therefore, inhibits gibberellin production much later in the biosynthetic pathway than triazole compounds (Rademacher 2000). The route of Moddus movement within the plant is both acropetal (upward) and basipetal (downward). Moddus is highly selective, flexible in timing of application and has much longer persistence in comparison with growth regulators belonging to other chemical groups. When crop is treated with Moddus some yield increase is expected even in the absence of lodging (Hafner 2001). Mixing certain fungicides (triazole and strobilurin) with Moddus enhances anti-lodging effect in winter rapeseed.

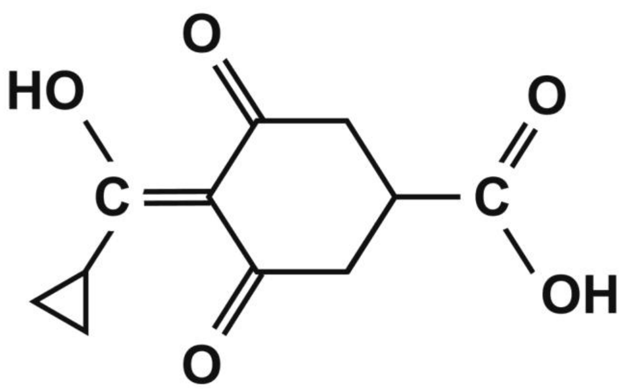


Figure 10: Chemical structure of trinexapac-ethyl (Rademacher 2000)

2.4.2 Agricultural applications of trinexapac

Lodging refers to the displacement of the stem from its vertical position and leaning towards the soil. Stem lodging is usually caused by the weight of water accumulated in the mature ears, wind and low stem resistance among other factors. Lodging hinders the mechanical harvesting process (Taiz and Zeiger 2004). Trinexapac prevents lodging not only due to reducing the crop height, but also through a direct strengthening of the stem and through increasing crown root structures (Hafner 2001, Espindula et al. 2009).

Trinexapac application enhances root length which improves the plant ability to scavenge for water and nutrients. In spring wheat, Trinexapac applications significantly improved nutrient acquisition and thus yield especially under water deficit. This was mainly due to an improvement of the root system being reflected in root fineness and root length. Grain yield and baking quality of wheat was improved by trinexapac due to a better assimilate translocation (Pitann et al. 2010). Trinexapac develops an optimum architecture of plant. Equal and maximum sunlight on throughout the canopy of plant helps to uniform ripening after Moddus application. Application of trinexapac increased the disease tolerance. Trinexapac produced healthy plants which are capable to decrease the intensity of diseases.

3. MATERIALS AND METHODS

3.1 Overview of Field Experiments

Total 9 field experiments were carried out in three consecutive years from 2008 to 2010 in two research stations (Giessen and Rauischholzhausen). An overview about these experiments is given in table 1.

Table 1: Overview of the executed field experiments

Experiment	Study Factor	Number of Treatments	Year	Location
1 & 2	Fungicide x Cultivar	8 x 2 = 16	2007-08	Giessen, RH[1)]
3 & 4	Fungicide	14	2008-09	Giessen, RH[1)]
5	Fungicide x Sulphur	14 x 2 = 28	2009-10	RH[1)]
6 to 9	Fungicide x Nitrogen	15 x 2 = 30	2008-10	Giessen, RH[1)]

[1)] Rauischholzhausen

3.2 Description of Experimental Locations

3.2.1 Experimental station Giessen

The experimental station Giessen is situated in the valley of the Lahn River at latitude of 50° 36´ North and a longitude of 8° 39´ East and at altitude of 158 m above sea level. The soil is classified as fluvogenic soil characterized by silty clay with clay content (0 – 30 cm) of 28 – 33%. Generally the soil is characterized by humus content of 2% (0 – 30 cm) and by available field capacity of 202 mm (0 – 100 cm). The chemical parameters of the soil are given in table 2.

Table 2: Chemical soil parameters of field experiments at Giessen in 2008–2010

Parameter	Unit	2008	2009	2010
NO_3-/NH_4-N				
0 – 30 cm	kg/ha	12.6	16.8	14.6
30 – 60 cm	kg/ha	11.6	15.8	14.0
60 – 90 cm	kg/ha	10.7	15.3	14.1
Total	kg/ha	34.9	48.0	42.7
pH (0 – 30 cm)		7.1	6.7	6.6
P (0 – 30 cm)	mg/100 g	7.91	11.03	11.16
K (0 – 30 cm)	mg/100 g	6.81	11.70	15.12
Mg (0 – 30 cm)	mg/100 g	15.32	16.50	9.80

Nitrogen and sulphur fertilizers were applied on the basis of soil analysis at different rates for different experiments. The fertilizer calcium ammonium nitrate (27% N) and ammonium sulphate (21% N + 24% S) were applied to meet the nitrogen and sulphur requirement of the crop.

Climatic conditions

The weather conditions during the growing period (including over wintering phase) of rapeseed (August to July) were characterized by mean air temperature of 8.5, 8.4 and 8.6°C and sum of precipitation of 660.5, 650.5 and 614.5 mm in 2008, 2009 and 2010 respectively (Table 3). In all growing years air temperature reached its maximum in July and August. Values of average air temperature and total precipitation of these growing years were not varied in comparison with last 20 years (1990-2010).

Table 3: Air temperature (°C) and precipitation (mm) data during the growth period of winter rapeseed in 2007-2010 and last 20 years (1990-2010) at Giessen

Months	Air Temperature °C (means/month)				Precipitation mm/year			
	2007/08	2008/09	2009/10	1990-2010	2007/08	2008/09	2009/10	1990-2010
August	14.5	18.6	18.5	17.2	129.5	70.0	43.8	61.1
September	9.4	9.7	11.4	13.7	67.7	74.8	38.5	51.3
October	5.9	8.2	8.2	9.0	7.6	55.9	48.1	50.2
November	3.1	4.3	6.1	4.3	58.7	30.3	94.0	58.3
December	0.7	-0.4	1.8	1.6	61.7	27.7	67.5	64.5
January	3.6	-2.1	-2.2	0.3	25.5	28.4	24.0	49.5
February	3.4	2.2	1.1	0.8	21.1	34.4	33.1	41.4
March	5.5	5.0	5.4	4.4	69.0	50.6	42.6	45.2
April	5.7	9.7	7.3	8.4	66.1	46.2	11.6	42.2
May	16.7	15.1	12.1	12.9	50.4	82.2	72.9	60.2
June	13.4	11.8	13.3	16.0	60.4	73.0	79.3	63.0
July	20.5	18.5	20.6	17.8	42.8	77.0	59.1	68.1
Mean	**8.5**	**8.4**	**8.6**	**8.9**	-	-	-	-
Sum	-	-	-	-	**660.5**	**650.5**	**614.5**	**655.0**

3.2.2 Experimental station Rauischholzhausen

The experimental station Rauischholzhausen is situated nearly Marburg (latitude 50° 45´N, longitude 8° 39´E, altitude 220 m above sea level). Soil conditions of Rauischholzhausen are characterized by loess soil which is formed by the accumulation of wind-blown silt and variable amounts of sand and clay that are loosely cemented by calcium carbonate. It is usually homogeneous and highly porous and is traversed by vertical capillaries that permit the sediment to fracture and form vertical bluffs. Generally the soil of Rauischholzhausen experimental station is characterized by the following parameters: clay content 25% (0–30 cm) humus content 2.4% (0–30 cm) and available field capacity 130 mm (0–100 cm). Chemical parameters of the soil are given in table 6. The nitrogen fertilizers calcium ammonium nitrate (27% N) and ammonium sulphate nitrate (27% N + 12% S) were applied to meet the nitrogen and sulphur requirement of the crop.

Table 4: Chemical soil parameters of field experiments at Rauischholzhausen in 2008–2010

Parameter	Unit	2008	2009	2010
NO_3-/NH_4-N				
0 – 30 cm	kg/ha	9.5	8.5	8.6
30 – 60 cm	kg/ha	5.6	4.7	4.9
60 – 90 cm	kg/ha	4.0	3.9	4.1
Total	kg/ha	19.1	17.1	17.6
pH (0 – 30 cm)		6.6	6.3	6.6
P (0 – 30 cm)	mg/100 g	3.44	7.25	3.83
K (0 – 30 cm)	mg/100 g	17.9	21.85	12.90

Climatic condition

The climatic data (air temperature and precipitation) at Rauischholzhausen for the growth period of winter rapeseed for all three years are presented in table 5. Mean air temperature of Rauischholzhausen was higher (+1^{o}C) and sum of precipitation almost equal to Giessen during growing years. The weather conditions during the growing period of rapeseed (August to July) were characterized by mean air temperature of 9.7, 9.2, 9.4°C and sum of precipitation of 637.5, 589.3, 676.7 mm in 2008, 2009 and 2010 respectively. In all growing years air temperature reached its maximum in July and August. Lowest temperature was recorded in the months of January and December. Mean values of air temperature and sum of precipitation in experimental years did not diverge strongly from the means of the last 20 years (1990 - 2010).

Table 5: Air temperature (°C) and precipitation (mm) data during the growth period of winter rapeseed in 2007-2010 and last 20 years (1990-2010) at Rauischholzhausen

Months	Air Temperature °C (means/month)				Precipitation mm/year			
	2007/08	2008/09	2009/10	1990-2010	2007/08	2008/09	2009/10	1990-2010
August	16.4	17.8	18.3	17.8	99.0	58.5	37.6	61.0
September	12.7	12.6	14.6	13.5	66.2	42.8	49.3	51.8
October	8.4	9.3	8.8	9.0	11.3	47.1	45.9	56.9
November	4.5	5.6	8.3	4.9	44.1	34.1	110.4	51.8
December	1.9	1.3	1.2	1.2	65.8	29.0	75.3	52.3
January	4.8	-2.9	-2.4	0.9	46.3	38.4	28.5	48.8
February	3.6	1.7	0.7	1.9	28.1	47.2	54.4	43.3
March	5.2	5.0	5.3	5.1	51.2	55.0	50.3	41.4
April	7.8	12.3	9.2	8.9	62.6	28.2	13.9	38.6
May	15.0	14.2	11.0	13.1	61.4	68.6	68.9	62.3
June	17.1	15.4	17.6	15.9	73.8	50.3	105.4	65.3
July	18.4	18.5	20.1	17.8	27.7	90.1	36.8	70.2
Mean	**9.7**	**9.2**	**9.4**	**9.2**	-	-	-	-
Sum	-	-	-	-	**637.5**	**589.3**	**676.7**	**643.7**

3.3 Design of the Field Experiments

3.3.1 Fungicide × cultivar experiment 2007-08

The experiment was laid out in randomized complete block design in factorial arrangement with four replications at both research stations. During this experiment two cultivars (cv. Elektra and cv. NK Fair) were taken under observation as a study factor. Five fungicides of triazole and strobilurin and one growth regulator trinexapac were used in seven combinations with control (Table 6) which was the second study factor. There were 16 treatments in each replication. Fungicides and growth regulator were applied at green floral bud (pre-flowering) stage (BBCH 53) and on the course of pod development stage (BBCH 65). A CO_2-charged hand boom-sprayer equipped with Tee Jet nozzles at 180 L/ha at a pressure 0.15 MPa was used for foliar application of fungicides and growth regulator in all field experiments at both experimental stations.

Chisel plow was used for tillage practices before sowing for all field experiment during 2007 to 2010 at both experimental stations. Net plot size was 5 m x 3 m with 12 rows by maintaining 20.8 cm row spacing in all field experiments at both research stations. The sowing was done in the last week of August at Giessen and Rauischholzhausen in all field experiments. “Hege 80” grain drill was used to sow rapeseed at 2 to 3 cm depth for all field experiments at both stations. During this experiment, planting density was maintained at the rate of 50 plants per m^2. Post emergence herbicide Butisan Top (metazachlor 12% + quinmerac 37.5%) was applied to eradicate weed to avoid weed losses at the rate of 1.8 L/ha at both experimental locations, whereas insect damage was controlled by applying Trafo (λ-cyhalothrin) at the rate of 150 g/ha at BBCH 57 in Rauischholzhausen, and Biscaya (thiacloprid 240 g/L) was applied two times at different growth stages of crop (BBCH 49 and BBCH 54) at the rate of 300 ml/ha in Giessen. The preceding crops from rapeseed were winter Barley at Giessen and winter Wheat at Rauischholzhausen. Sulphur was applied at the rate of 72 kg/ha at growth stage of BBCH 18 in the form of ammonium sulphate. Nitrogen was applied with a total amount of 150 kg/ha in two doses at different growth stages of crop (BBCH 18 and BBCH 30) in the form of calcium ammonium nitrate and ammonium sulphate. For each plot, a combined plot harvester (Wintersteiger) was used to harvest 4 central rows at Giessen and all rows at Rauischholzhausen in the last week of July when the air temperature reached at its maximum point for all field experiments at both experimental locations.

Table 6: Fungicides and growth regulator treatments, dose and timing of application at Giessen and Rauischholzhausen in 2007-2008

No.	1st application BBCH 53		2nd application BBCH 65	
	Fungicide & growth regulator	Dose (L/ha)	Fungicide & growth regulator	Dose L/ha
1	Control (without fungicide and growth regulator)			
2	Toprex	0.5	-	-
3	Toprex	0.5	Ortiva	1.0
4	Toprex	0.35	Ortiva	1.0
5	Toprex + Moddus	0.35 + 0.5	Ortiva	1.0
6	-	-	Ortiva	1.0
7	Folicur	1.0	Proline	0.7
8	Caramba	1.0	Cantus	0.5

3.3.2 Fungicides and fungicide × sulphur experiment 2008-10

The experimental design of the experiments was a randomized complete block design in 2009 and a two factorial randomized complete block design in 2010 with four replications at both locations. Nine fungicides (triazoles and strobilurins) and one growth regulator (trinexapac) were used in 13 combinations with comparison of control (Table 7). In 2010 these fungicides were tested in duplicate under two levels of sulphur (S_1 = 0 kg/ha and S_2 = 72 kg/ha). Fungicides and growth regulator were applied at green floral bud stage (BBCH 53) and on the course of pod development stage (BBCH 65).

Table 7: Fungicide and growth regulator treatments, dose and timing of application in 2008-2010

No.	1st application BBCH 53		2nd Application BBCH 65	
	Fungicide & growth regulator	Dose (L/ha)	Fungicide & growth regulator	Dose(L/ha)
1	Control (without fungicide and growth regulator)			
2	Folicur	0.75	-	-
3	-	-	Caramba	1.0
4	-	-	Cantus	0.5
5	-	-	Prosaro	0.75
6	-	-	Proline	0.5
7	-	-	Harvesan	0.75
8	Moddus	0.5	Cantus Gold	0.5
9	-	-	Moddus	0.5
10	-	-	Ortiva	1.0
11	Toprex	0.5	-	-
12	Toprex	0.5	Ortiva	1.0
13	Folicur	1.0	Oriva	1.0
14	Caramba	1.0	Ortiva	1.0

Planting density was maintained at the rate of 50 plants per m^2. Post emergence herbicide Butisan Top (metazachlor 12% + quinmerac 37.5%) was applied to control weed to avoid weed losses at the rate of 1.8 L/ha at both experimental stations, whereas insect damage was controlled by applying Karatay Zeon (λ-cyhalothrin 100 g/L) at the rate of 75 mL/ha at BBCH 51 at Rauischholzhausen Biscaya (thiacloprid 240 g/L) was applied at the rate of 300 ml/ha at BBCH 50 in Giessen. The preceding crops from rapeseed were winter barley at Giessen and winter wheat at Rauischholzhausen in both 2009 and 2010. Sulphur was applied at the rate of 72 kg per ha at both station in 2009. Nitrogen was applied with a total amount of 150 kg/ha in two doses at different growth stages of crop (BBCH 18 and BBCH 30) in the form of calcium ammonium nitrate.

3.3.3 Fungicide × nitrogen experiment 2008-10

The experiments with cv. Fangio were laid out in two factorial randomized complete block design with four replications at both research stations. Seven fungicides belonging to triazoles and strobilurins and one growth regulator trinexapac were used in fourteen combinations with control (Table 8) which was the first study factor. Fungicides and growth regulator were applied at four leaf stage (BBCH 16), green floral bud (pre-flowering) stage (BBCH 53) and on the course of pod development stage (BBCH 65). Nitrogen was used as a second study factor in these experiments. Nitrogen was applied in the form of calcium ammonium nitrate and ammonium sulphate. High (270 kg/ha) and low levels (200 kg/ha) of nitrogen were tested which were applied in three splits.

Nitrogen fertilization

N_1= 50 + 120 and 100 kg/ha (autumn, BBCH 18 and BBCH 53)

N_2= 30 + 90 and 80 kg/ha (autumn, BBCH 18 and BBCH 53)

Table 8: Fungicide and growth regulator treatments, dose and timing of application in 2008-2010

No.	1st Autumn application		2nd application BBCH 53		3rd Application BBCH 65	
	Treatment	Dose L/ha	Treatment	Dose L/ha	Treatment	Dose L/ha
1	Control (without fungicide and growth regulator)					
2	Caramba	0.7	-	-	-	-
3	Folicur	0.7	-	-	-	-
4	Moddus	0.5	-	-	-	-
5	-	-	Caramba	1.0	-	-
6	-	-	Folicur	1.0	-	-
7	-	-	Moddus	0.5	-	-
8	-		Caramba	1.0	Cantus Gold	0.5
9	-	-	Folicur	1.0	Cantus Gold	0.5
10	-	-	Moddus	0.5	Cantus Gold	0.5
11	-	-	Caramba + Moddus	0.8 + 0.5	Cantus Gold	0.5
12	-	-	Carax	1.0	Proline	0.7
13	-	-	Carax	1.0	Ortiva	1.0
14	-	-	Toprex	0.5	Proline	0.7
15	-	-	Toprex	0.5	Ortiva	1.0

During this experiment, 45 plants per m^2 were maintained at both stations. In Giessen weeds were eradicated by applying Fuengo (triasulfuran 70%) at the rate of 1.5 L/ha at BBCH 0 and Fox (bifenox 480 g/L) was applied at the rate of 0.5 L/ha at BBCH 18 at Giessen. In Giessen insect control was done by applying Mavrik (taufluvalinate 22%) at the rate of 200 ml/ha at BBCH 51 and Biscaya (thiacloprid 240 g/L) was applied at the rate of 300 ml/ha at BBCH 54. Post emergence herbicide Butisan Top (metazachlor 12% + quinmerac 37.5%) was applied to control weed to avoid weed losses at the rate of 1.8 L/ha, whereas insect damage was controlled by applying Karatay Zeon (λ-cyhalothrin 100 g/L) at the rate of 75 ml/ha at BBCH 51 in Rauischholzhausen. The preceding crops from rapeseed were winter barley at Giessen and winter wheat at Rauischholzhausen in both years 2009 and 2010. Sulphur was applied at the rate of 72 kg/ha at growth stage of BBCH 18 in the form of ammonium sulphuric acid.

3.4 Study Parameters

All measured parameters are overviewed in table 9.

Table 9: Overview of all measurements recorded during field experiments at Giessen (GI) and Rauischholzhausen (RH) in 2008, 2009 and 2010

Parameters	Unit	Experi. I		Experi. II			Experi. III			
		Fun. × Cv.		Fun.		Fun. × S	Fun. × Nit.			
		GI	RH	GI	RH	RH	GI		RH	
		2008	2008	2009	2009	2010	2009	2010	2009	2010
Physiological, morphological and yield parameters										
LAI	m^2/m^2	✓ 1)	x	✓	x	✓	✓	✓	x	✓
Planting stand	cm	✓	✓	✓	✓	✓	✓	✓	✓	✓
Main branches/plant	No.	✓	x	✓	x	✓	✓	✓	x	✓
Sub branches/plant	No.	✓	x	✓	x	✓	✓	✓	x	✓
Main stem length	cm	✓	x	✓	x	✓	✓	✓	x	✓
Seeds/pod	No.	✓	x	✓	x	✓	✓	✓	x	✓
Pod length	cm	✓	x	✓	x	✓	✓	✓	x	✓
Pods/plant	No.	✓	x	✓	x	✓	✓	✓	x	✓
Plant height	cm	✓	x	✓	x	✓	✓	✓	x	✓
Pod elasticity	No.	✓	x	✓	x	x	x	✓	x	✓
1000-grain weight	g	✓	✓	✓	✓	✓	✓	✓	✓	✓
Seed yield	dt/ha	✓	✓	✓	✓	✓	✓	✓	✓	✓
Quality Parameters										
Oil content	%	✓	✓	✓	✓	✓	✓	✓	✓	✓
Protein content	%	✓	✓	✓	✓	✓	✓	✓	✓	✓
Glucosinolates	mmol/g	x	x	x	x	✓	✓	✓	✓	✓
Free fatty acids	%	✓	✓	✓	✓	✓	✓	✓	✓	✓
Value of peroxides	meq/kg	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fatty acid concentration	%	✓	✓	✓	✓	✓	✓	✓	✓	✓
Diseases and lodging										
Phoma lingam	1-9	✓	x	✓	✓	✓	✓	✓	✓	✓
Sclerotinia sclerotiorum	1-9	✓	x	✓	✓	✓	✓	✓	✓	✓
Lodging	1-9	✓	✓	✓	✓	✓	✓	✓	✓	✓

1) ✓ = measured, **x** = not measured

3.4.1 Field parameters

Leaf area index (LAI)

Weekly, LAI was measured using a pre-calibrated Sun Scan canopy analysis system from Delta T Company. Sun Scan measures the incident and transmitted photosynthetically active radiations (PAR) in crop canopies. The advantage of using Sun Scan lies in its capability to function in both steady as well as changing light conditions. The system consists of a probe, a beam fraction sensor (BFS), and a data collection terminal (also called a Psion or Work about) containing Sun data software for programming the system. The BFS contain two photodiodes, one of which could be shaded from the direct solar beam by the shade ring.

This allowed the direct and diffuse components of PAR to be separated. BFS therefore measured the actual solar light incident on the canopy. The Sun Scan probe is a 1 meter long light sensitive rectangular rod containing 64 photodiodes equally spaced along the 1m length. It ends in a handle containing batteries and ports to which the work about and BFS are connected. It also contains electronics that function in converting the photodiode output from the “Wand„ into digital PAR readings. The readings are then sent to the data collection terminal (Psion Work about) via an RS232 link (cables). In these experiments readings directly represented the true leaf area indices of rapeseed plant.

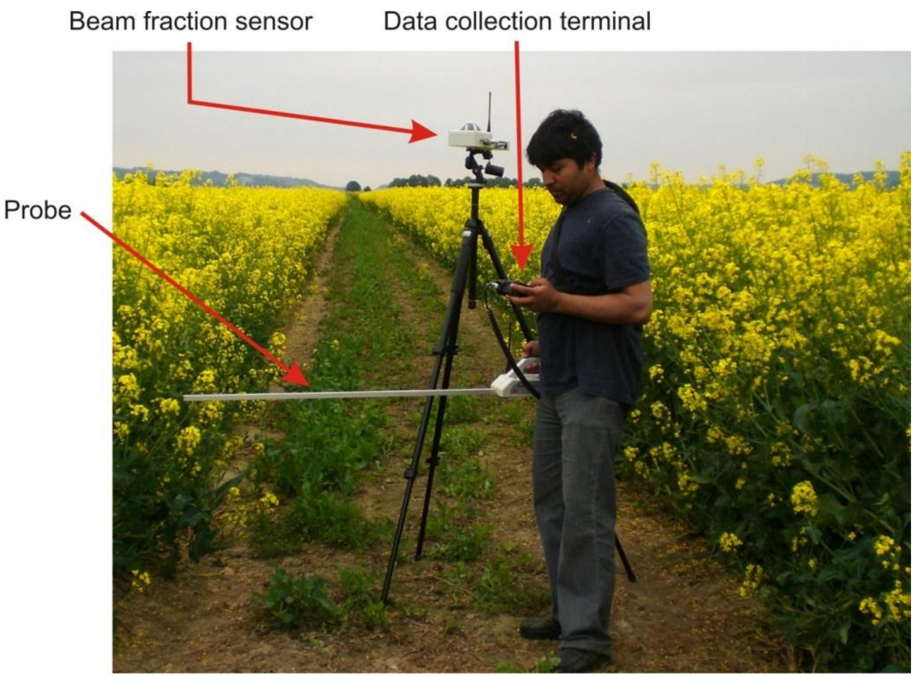


Figure 11: Leaf area index measurement at Rauischholzhausen 2010

LAI measurements procedures constituted mounting the beam fraction sensor to a tripod and connecting to the probe via cables. From the probe the work about was connected via the RS232 link. By positioning the BFS in an unshaded position and inserting the probe beneath the canopy shadow of targeted plants in the middle two rows of each plot, the leaf area index was obtained by directly reading the values displayed by the work about. Data was collected in duplicate from each plot.

Planting stand

Height of planting stand was measured with fortnight interval. From each plot, two readings were measured for planting stand and the average was calculated.

Measurement of planting stand was started from BBCH 51 till maturity. Planting stand was measured using a normal bricklayer ruler.

Plant morphology

At Giessen in 2008 main stems of ten plants from each plot were separated with hand cutter. From these samples of main stem different measurements were made which included main stem length, green and mature pods per main stem and seeds per pod of main stem. Height of main stem from soil surface to 1st side branch was measured from 5 plants of each plot from four replications at Giessen in 2009 and 2010, while 20 plants of each plot from one replication at Rauischholzhausen in 2010. These plant samples were taken manually with sharp cutter. After that these plant samples were hanged in the store room for drying. After two months all measurements were recorded from these plants. From these collected samples of plants number of main branches which are directly attached to the main stem and sub branches which are initiated from main branches per plant were counted. Plant height and pod length was also measured from these plant samples.

Seed yield and its components

Collected plant samples at both experimental stations were also used for measuring seed yield components. Pods of these collected plant samples were separated from plant with sharp knife and number of pods per plant was obtained by averaging pods from the all plants. 20 pods from each plant were taken and total 100 pods from each plot of 4 replications at Giessen and 400 pods from each plot of one replication at Rauischholzhausen were separated. These pods were threshed with a small electric thresher which separated seeds from pods. After that these seeds were counted with contador. Seeds per pod were determined by dividing pod number on total number of seeds.

Harvesting of rapeseed is a critical operation due to smaller size of seeds and shattering of pods at maturity time. Harvesting was accomplished when pods were dried and rattle when shaken, seed color was brown to dark and stems were still be partly green. Moisture content in the seeds was regularly examined at maturity time. Harvesting was done when moisture content in the seeds was in the range of 9 to 14%. For each plot, a combined plot harvester (Wintersteiger) was used to harvest 4 central rows at Giessen and all rows at Rauischholzhausen. Seed sample of each plot was cleaned with air pressure and weighed to determine seed yield of per ha. 1000 grain weight was used to calculate seed size. Using an automated seed counter (Contador), 500 seeds were sampled twice and then weighed using a thousand grain weight (TGW). Seed yield and TGW were adjusted to moisture content of 9%.

Estimation of diseases and lodging incidence

A visual scale of 1 to 9 for *Phoma lingam* and *Sclerotinia sclerotiorum* (Anon 1976) was used for their assessment. Scale 1 showed completely healthy plant without any infection of respective disease. As scale number increased level of disease intensity was also increase. 9 stated for completely attacked plant.

Disease of *Phoma lingam* was assessed by taking 25 plants of each plot. These plants were uprooted with spade after that stem of each plant was separated from root. These parts of plant were visually observed to know the severity of disease on the basis of Fig. 12. A number was granted to every plant on the basis of severity level. Average of all plant numbers gave us one number which showed the intensity of *Phoma lingam* in this plot.

Attack of *Sclerotinia sclerotiorum* was estimated in standing crop of rapeseed at BBCH 70. All plants in 2 meter long of middle four rows of each plot were examined for *Sclerotinia sclerotiorum* on the basis of Fig. 12. Like *Phoma lingam* here also on the basis of disease symptoms one number was given to each plant. Average value of all plants in each plot gave one number which showed the intensity of disease.

A B

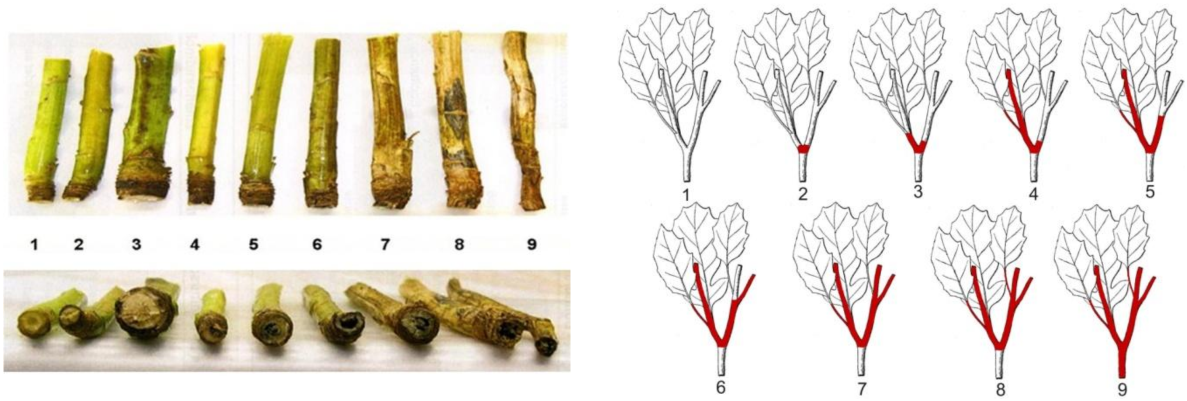


Figure 12: Keys used for assessment of *Phoma lingam* (A) and *Sclerotinia sclerotiorum* (B)

Data of Lodging was recorded at BBCH 80 from each experiment in all growing seasons. A visual scale of 1 (erect) to 9 (flat) was used to observe lodging. Rate of lodging was estimated from both sides of each plot.

3.4.2 Quality parameters

Oil content

Soxhlet method of oil extraction was used to measure the oil content of rapeseed (Jensen 2007). In this method oil was extracted from solid material by repeated washing (percolation) with an organic solvent (Hexane) in a special glassware. The procedure of soxhlet provides a soaking effect and does not permit channeling.

Equipment: Coffee grinder, **Soxhlet apparatus:** cellulose extraction thimble and cotton wool, condenser, soxhlet extractor, 250 ml flat bottom flask pre dried with boiling chips or glass beds, heating mantle **Chemical:** Hexane

Figure 13: Soxhlet apparatus used for measurement of oil content

100 g seeds of rapeseed were grounded with coffee grinder for 2 minutes. The ground seed material was dried in an oven for 3 hours at 105°C. Then 5 g sample was weighed from this oven dried material in cellulose extraction thimble. Put a small piece of cotton wool at the bottom of cellulose thimble before taking the sample and also cover the top of thimble with cotton wool after the sample to prevent floating. Weigh pre dried flat bottom flask with boiling chips. The thimble was placed in an extraction chamber which was suspended above a flask containing Hexane of 200 mL. Extraction chamber with thimble and hexane and boiling chips containing flask was connected with condenser. Before start heating at 69°C, opened the flow of cold water in the condenser. When flask was heated and the Hexane evaporated and moved up into the condenser where it was converted into a liquid that trickles into the extraction chamber containing the sample. The extraction chamber was designed so that when the solvent surrounding the sample exceeds a certain level it overflows and trickles back down into the boiling flask. This process of boiling was continued for 8 hours. At the end the flask containing oil and small amount of hexane was separated and put into an oven for 2 hours at 95°C. After that, flask which contains extracted oil and boiling chips was weighed. Calculate the percent of oil in the original sample as given below;

Mass of Oil = (wt of flask + extracted oil + boiling chips) - (wt of flask + boiling chips)

$$\text{Oil content (\%)} = \frac{\text{mass of extracted oil (g) x 100}}{\text{mass of sample (g)}}$$

Fatty acids

Fatty acids were analyzed by using Gas chromatography (Varian CP-3800) (Sepännen-Laakso 2002). Gas Chromatography (GC) is the main technique in fatty acid analysis owing to its sensitivity, speed, high resolution and reproducibility. To analyze the fatty acid composition of rapeseed, oil of rapeseed must be pretreated so that the individual fatty acids are available for chromatographic analysis. For this purpose, fatty acids are converted to fatty acid methyl esters (FAME) to make them volatile for GC analysis. Acid-catalyzed and base-catalyzed methods are commonly used for FAME derivatization. In these experiments, FAME was prepared by sodium methylate (alkaline)-catalyzed transesterification for GC analysis which is described as follows;

Preparation of FAME

Equipments: Clean seeds of rapeseed, coffee grinder, volumetric flask (50 mL), test tube (4 mL), centrifugal, pipette, Glass vial **Chemicals:** Petroleum benzene, methanol, Iso-octane, Na-methylate

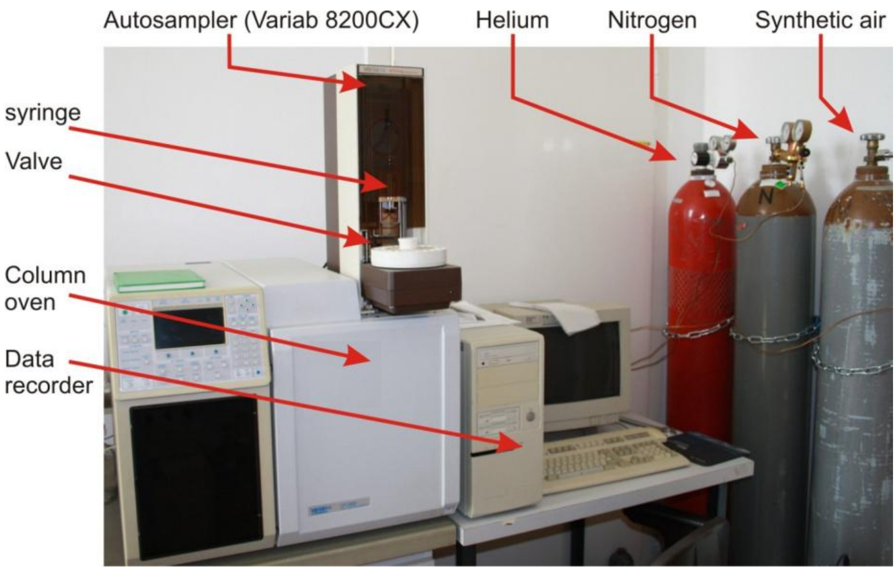


Figure 14: Gas chromatography (Varian CP-3800)

5 g seeds of rapeseed were grounded with coffee grinder for 2 minutes. Then 0.3 g grounded seed sample was taken in 50 mL volumetric flask. 3 mL petroleum benzene was added in this volumetric flask. This flask was centrifuged at 3000

circle/min for 5 min. The mixture was placed in a refrigerator for 30 min during which the fats of the seed samples were dissolved by the petroleum benzene. 500 µl of the surface transparent liquid of volumetric flask were pipetted and transferred to a 4 mL test tube. Test tube was kept in a desiccator for 24 hours. Next day only oil was present in the test tube due to evaporation of petroleum. 2mL of Na methylate was added to the test tube and put it for 30 min in a refrigerator. After 30 min, 1 mL iso-octane was added. As isooctane is not soluble in sodium methylate, two liquid phases were formed in the tube and most part of the fatty acid esters were transferred to the isooctane portion. From upper surface of liquid in test tube, 500 ul was pipetted to a glass vial and made ready for GC analysis after mixing with 200 ul of iso-octane.

GC analysis

For quantification of fatty acids, prepared sample of FAME was analyzed using a GC which was equipped with flame ionization detector (GC-FID).

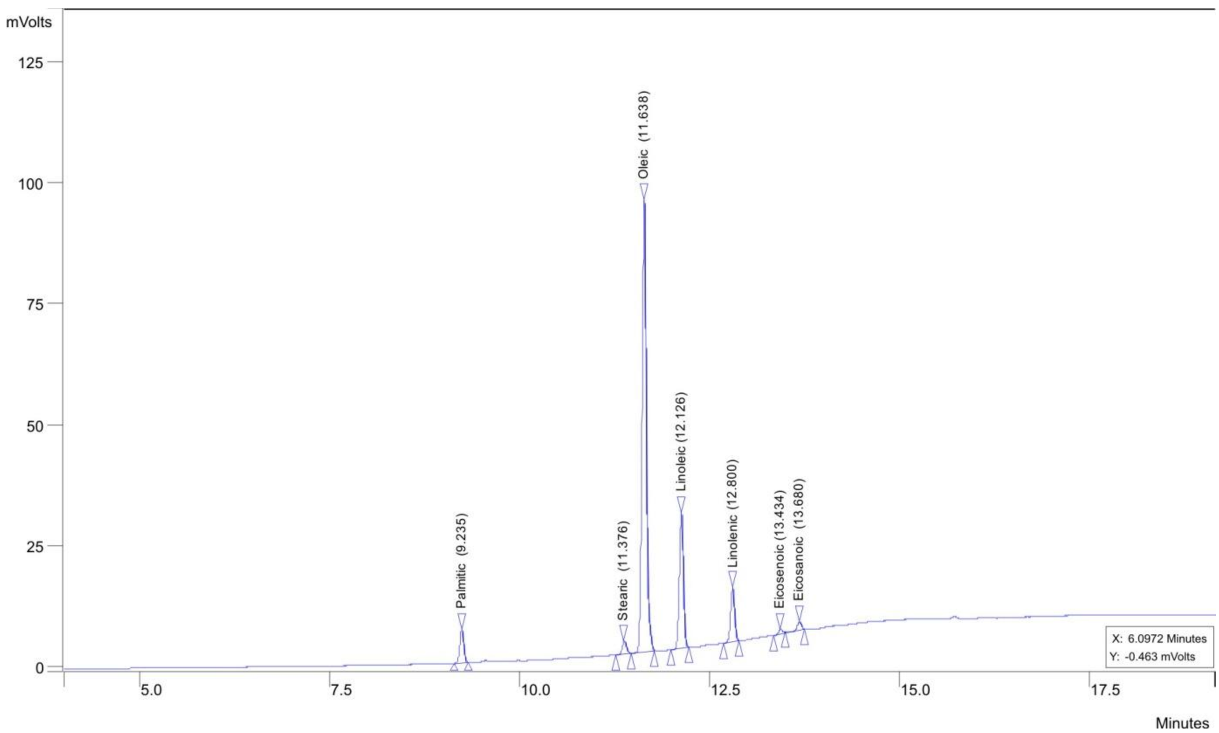


Figure 15: Chromatograph for one of the oil sample showing peaks for different measured fatty acids

A capillary column OPTIMA - FFAP-Wax (25 m x 0.32 mm i.d; film thickness 0.25 µm) with CP-SIL 88 foe FAME stationary phase, which was equipped with CS-fused-Silica per-column, was used for separation of fatty acids. Helium was used as the carrier gas with a flow rate of 1.1 ml/min. Temperature was programmed between 160^{o}C and 260^{o}C with a ramp rate of 5^{o}C/min for 17 minutes duration. The injector and detector were maintained at 240 and 270^{o}C, respectively. A sample of 1 µl was injected with 1:50 split ratio by an auto sampler (Varian 8200 CX). After components of the mixture move through the GC column, they reach a detector. Ideally, components of the mixture will reach the detector at varying times due to differences in the partitioning between mobile and stationary phases. The percentage of individual fatty acid was computed from peak areas. Peak area of each fatty acid was proportional to its number of molecules in the sample (Fig. 15). Response factors of detector and FID normalization were considered for data processing. Correction factor was calculated by using standard FO8. This correction factor was multiplied with the amount of fatty acid quantified for the sample. Correction factor was computed by using the following formula;

$$\text{Correction factor} = \frac{\text{detected concentration of fatty acid from FO8 sample}}{\text{actual concentration of fatty acid from FO8 sample}}$$

Peroxide value (PV)

The peroxide value (PV) is an indication of the amount of hydro peroxides (Primary oxidation products) present in the oil. These compounds arise from oxidation of polyunsaturated fatty acid of rapeseed. The peroxide value is found to increase with the storage time, temperature, trace amount of heavy metals and contact with air of the oil (Siddique et al. 2010).

Iodometric titration method (AOCS 1998b, IUPAC 1987) was used for determination of peroxide value in the oil of rapeseed from all executed field experiments at both stations. In this method PV can be detected on the basis of conversion of iodide to iodine by hydro peroxides in acidic conditions. The iodine that is formed is then titrated with sodium thiosulphate solution, the titrate value giving a quantitative measure of peroxides.

$ROOH + KI_{excess} \rightarrow ROH + KOH + I_2$

$I_2 + starch + 2Na_2S_2O_3\ (dark) \rightarrow 2NaI + starch + Na_2S_4O$

PV expressed as milliequivalent oxygen per kilogram oil (meq/kg), is a measure of oil quality. Used method of titration was described as follows;

Equipments: Conical flask with stopper, balance, electric magnetic stir, micropipette, a glass burette **Chemicals:** Acetic acid and Iso-octane solution 3:2 (v/v), distillated water, saturated potassium iodide solution, 0.01N sodium thiosulphate, starch

For PV measurement, oil was extracted from the seeds of rapeseed by using electric oil pressing machine at Giessen for all seed samples. Accurately weighed 5.0 ± 0.05 g oil extracted sample into a 250 mL conical flask with stopper. Exactly, 30 mL of 3:2 acetic acid/iso-octane solutions was added in conical flask. With micropippet, 0.5 mL of saturated potassium iodide solution was added to flask and was shaken for 60s. The iodide reacts with the peroxides in acid solution. The color of the solution changed to yellow-orange, and immediately 30 mL of distilled water and 0.5 g starch was added. Then the solution of sodium thiosulphate was added drop wise with a glass burette and continuously swirled with electric magnetic stir. This titration against sodium thiosulphate was continued until the solution became colorless. Then record the total added sodium thiosulphate volume. PV was calculated by using the following formula;

$$\text{Peroxide value (PV) meq/kg} = \frac{(a\text{-}b) \times N \times 1000}{E}$$

where
a is the volume (mL) of sodium thiosulfate required to titrate the sample
b is the volume (mL) of sodium thiosulfate required for the blank
N is the calculated normality of the standardized sodium thiosulfate solution
W is the weight of the sample (g)

Free fatty acids (FFA)

The acid value is a measure of the amount of free fatty acids present in a given amount of oil. The number of milligram of sodium hydroxide required to neutralize the acidic constituents in 1 g oil of rapeseed defined the free fatty acid percentage. In these experiments acid value of oil samples was determined by using simple chemical titration method (AOCS 1989). This method is described as follows;

Equipments: 250 mL conical flask, a glass burret, balance, electric magnetic stir
Chemicals: Ethanol + Toloul (1/1vv), 1% Phenolphthalein, 0.01N Sodium hydroxide

For calculating FFA via acid value, oil was extracted from the seeds of rapeseed by using electric oil pressing machine at Giessen for all seed samples. 10.0 ± 0.05 g of oil sample was weighed into a 250 mL conical flask. Then 50 mL of ethanol/toloule (1:1 v/v) mixture was added to the oil sample in the flask. 3 to 4 drops of Phenophthalene was also added into the mixture of flask as an indicator. Then the solution of 0.01N sodium hydroxide was added drop wise with a glass burette and vigorously swirled with electric magnetic stir. This titration against sodium hydroxide was continued until the solution attained pink color which persisted for 30s. Then record the total added sodium hydroxide volume. Acid number was calculated by using the following formula;

$$\text{Acid value} = \frac{40.0 \times a \times M}{W}$$

Where
40.0 is the molecular weight of NaOH (g/mole)
a is the volume (mL) of sodium hydroxide required to titrate the sample
M is the calculated normality of the standardized sodium hydroxide solution (mol/L)
W is the weight of the oil sample (g)
Calculated acid value was used for computation of FFA (%) by using the following formula;

$$\text{FFA (\%)} = \frac{\text{Acid value} \times \text{MGs} \times 100}{40.0}$$

Where, MGs is the average molecular weight of fatty acids in the oil of rapeseed

Protein and glucosinolate contents

The protein content in the seed samples of rapeseed was assessed by Dumas combustion method (AOCS1998a), using CHNS analyzer EA1110 type thermo Finnegan from field experiments in 2008 and 2009 and Near-infrared reflectance spectroscopy (NIRS) model 6500 (Tkackuk 1981) was used to determine protein and glucosinolates from those field experiments where nitrogen and sulphur were applied as second study factor with fungicides at both stations.

CHNS analyzer

The CHNS analyzer used to determine the percentage of nitrogen in the seed samples of rapeseed, based on the principle of "Dumas method" which involves the complete and instantaneous oxidation of the seed sample by flash combustion (Fig. 16). The combustion products are separated by a chromatographic column and detected by the thermal conductivity detector which gives an output signal proportional to the concentration of nitrogen in the sample. The Dumas combustion method was introduced in 1831 by Jean Baptiste Dumas. The Dumas combustion method for estimating the total (crude) protein content in the seeds of rapeseed is a simpler, faster, cheaper, and safer method which was described as follows;

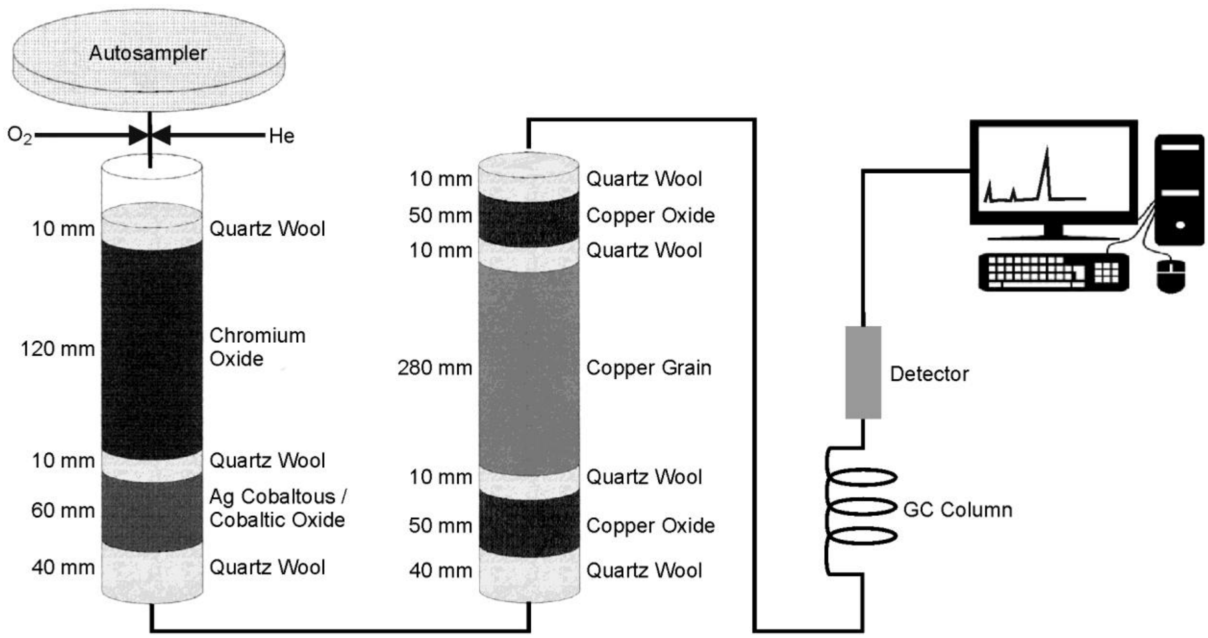


Figure 16: Dumas combustion method for nitrogen measurement with CHNS analyser (EA1110)

In Dumas method, seeds of rapeseed were grounded in Coffee grinder for two min. Grounded seed samples were dried in oven at 105^{o}C for 3 hours.10 milligram sample weighed with analytical balance (Sartorius) in a tin capsule which was dropped into a quartz tube at 1020^{o}C with constant helium flow (carrier gas). A few seconds before the sample drops into the combustion tube, the stream was enriched with a measured amount of high purity oxygen to achieve a strong oxidizing environment which guaranteed almost complete combustion/oxidation. All carbon in the sample was converted into carbon dioxide and nitrogen containing compounds into nitrogen oxide and N_2 during the flash combustion. The nitrogen oxide was reduced to N_2 in copper reduction column at 750^{o}C. The produced gases were separated by gas chromatography and then passed through a thermal conductivity detector that generates electrical signal which was proportional to the amount of gas produced by combustion gave the percentage of nitrogen in the sample. The analysis time per sample was 4 min. The nitrogen determined was converted to protein after multiplying with factor 6.25. Atropine ($C_{17}H_{23}NO_3$) was tested as a standard after every 30 samples of rapeseed to know correction factor. This correction factor was multiplied with the amount of nitrogen percentage quantified for the sample. Correction factor was computed by using the following formula;

$$\text{Correction factor} = \frac{\text{detected amount of nitrogen (\%) in atropine}}{\text{actual amount of nitrogen (\%) in atropine}}$$

Protein content % = detected amount of nitrogen in seed sample x corr. factor x 6.25

NIRS analysis

The NIRS technique is fast, nondestructive, cost effective, environmentally safe, and allows the simultaneous estimation of several traits in a unique measurement. The crude composition of intact seeds of rapeseed, including protein and glucosinolates were determined by near-infrared reflectance spectroscopy using the NIR System 6500 with WinISI II software (FOSS GmbH, Rellingen, Germany) as described by Daun (1995), using a standardization and calibration (NIRS-Networks for Rapeseed) from the German Agricultural Analysis and Research Organisation VDLUFA (Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten, Kassel, Germany). Protein and glucosinolate content was measured from seed samples of those field experiments in 2009 and 2010 where sulphur and nitrogen was taken as study factor at both experimental stations.

For determination of protein and glucosinolates, 3-4 g intact cleaned seeds (approxi. 500 seeds) of rapeseed were taken in sample cups (4 mm thick/38 mm). Seed samples inside cups were covered with sample cup lids (diameter 3.5 cm). Then sample cup was inserted into standard ring for scanning. Each sample last 1 min. for scanning. Protein content in the seeds of sample was analyzed spectroscopically by measuring wave lengths in the near infra red region of the light. Different components in the seeds of rapeseed due to having different bonding, absorbed and reflected specific wavelengths over the infrared range (750 to 2500 nm) in NIRS. N-H bonding in protein of sample absorb specific wavelength of radiation which was used for computation of protein content. Calibration was carried out by using VDLUFA before scanning of every sample.

3.5 Statistical Analysis

Statistical package PIAF (Programm Information Auswertung Feldversuche (Program for Statistical Evaluation of Field Trials) {Dr. Andrea Zenk (modifier) und Volker Michel (conception)} was used for checking the significance of the different treatments used. 5% probability level was used for studying the difference between different experimental treatments. Least significance difference (LSD) test at 0.05 was used to compare different treatment means. The standard deviations (SD) showed in figures were calculated by using Microsoft Excel.

4. RESULTS

4.1 Fungicide × Cultivar Experiment at Giessen 2007-08

4.1.1 Field parameters

Leaf area index (LAI)

Fungicidal treatments and cultivars did not show any significant differences in LAI of rapeseed at growth stages i.e. BBCH 62, BBCH 70 and BBCH 75, whereas significant variations were observed at BBCH 80 (Table 10). No interaction was observed between fungicides and cultivars for LAI at all growth stages of measurement. Inclusion of Ortiva in the mixture of Moddus and $Top_{0.35}$ improved LAI significantly than that of Control and Ortiva alone applied treatments, while it was statistically similar with that of all other fungicidal treatments at BBCH 80. Statistically lower value of LAI was recorded by alone application of Ortiva and combined application of Folicur with Proline than that of $Top_{0.35}$ + Ortiva, and was significantly higher in comparison with control at BBCH 80.

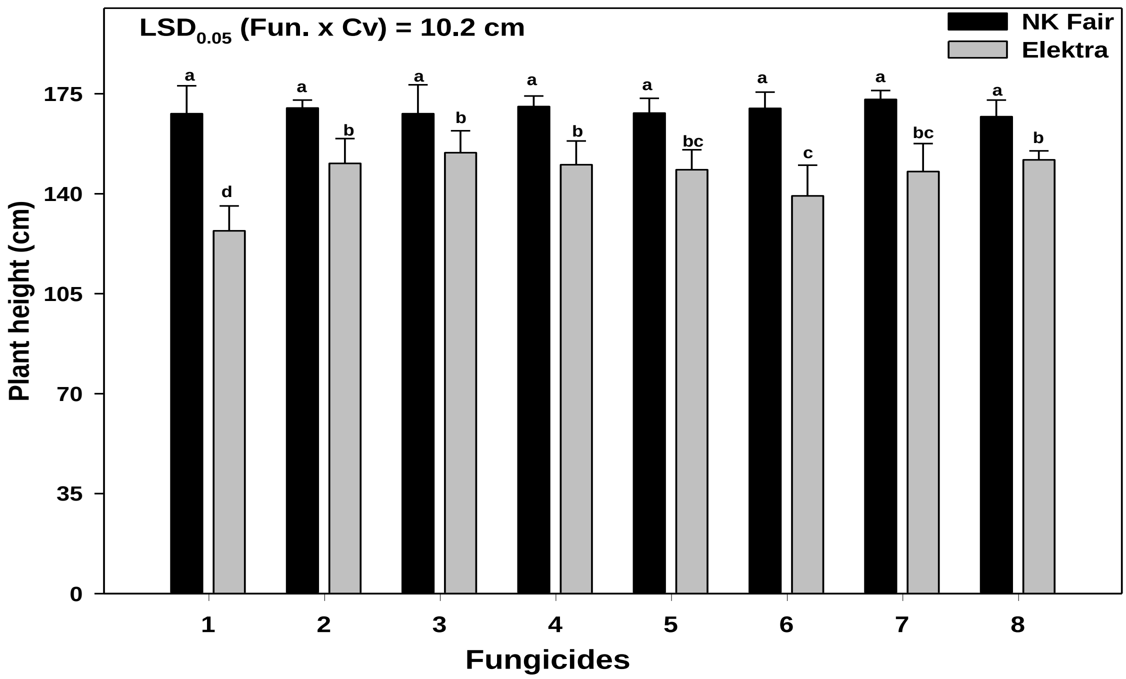
Table 10: Effect of fungicides and growth regulator on leaf area index (LAI), lodging and plant height (PH) of two cultivars of rapeseed at Giessen 2007-08

Treatments	LAI				Lodging (1-9)	PH (cm)
	BBCH 62	BBCH 70	BBCH 75	BBCH 80	BBCH 80	BBCH 80
Control	7.29	6.06	4.34	2.91 d	5.3	147.5 b
Toprex ($Top_{0.5}$)	7.08	6.41	4.59	3.64 ab	4.1	160.3 a
$Top_{0.5}$ + Ortiva	7.78	6.64	5.07	3.99 a	3.9	161.2 a
$Top_{0.35}$ + Ortiva	7.32	6.31	4.94	3.54 bc	4.5	160.3 a
$Top_{0.35}$ + Moddus + Ortiva	6.68	6.00	4.71	3.76 ab	3.3	158.3 a
Ortiva	6.96	5.78	4.49	3.33 c	4.6	154.6 ab
Folicur + Proline	6.77	5.93	4.73	3.45 bc	3.6	160.4 a
Caramba + Cantus	6.95	6.23	4.78	3.79 ab	3.5	159.4 a
Fun. ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**0.36**	**-**	**7.2**
NK Fair	7.01	6.24	4.70	3.72 a	3.5	169.2 a
Elektra	7.20	6.10	4.71	3.39 b	4.8	146.3 b
Cv. ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**0.18**	**-**	**3.6**
Fun. x Cv. ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**ns**	**-**	**10.2**

Application of triazole fungicides (Folicur + Proline) decreased the value of LAI compared with combined application of triazole (Toprex) and strobilurin (Ortiva) at all growth stages of measurement. Caramba + Cantus application also improved LAI significantly at the later stages of rapeseed compared with Control and alone application of Ortiva. Significant reduction in LAI was observed from untreated plots than that of all other fungicidal treatment at BBCH 80. Alone application of Toprex at the rate of 0.5 L/ha as well as in combination with Ortiva led to significant higher values of LAI (3.64 and 3.99) over control (2.91) and alone application of Ortiva (3.33) at BBCH 80. Cv. NK Fair increased LAI (3.72) significantly compared with cv. Elektra (3.39) at BBCH 80.

Plant height

Plant height (PH) was significantly affected by application of fungicides at BBCH 80 Table 140). Rate of lodging had inverse relation with PH. Heavy lodged plots which were treated by Ortiva alone and control (untreated) gave minimum values of PH, while highest values of PH were recorded from other lower lodged plots. Statistical lowest value of PH (147.5 cm) was obtained from control plots in comparison with other all fungicidal treatments with the exception of alone application of Ortiva. Significant differences were observed among cultivars regarding PH. Cv. Elektra exhibited minimum value of PH (146.3 cm) due to its more susceptibility to lodging compared with cv. NK Fair (169.2 cm) which resist to lodging. Interaction between fungicides and cultivar was statistically significant for PH of winter rapeseed at BBCH 80 (Fig. 17). Application of Folicur + Proline led to maximum PH (173 cm) in cv. NK Fair, while $Top_{0.5}$ + Ortiva treated plants exhibited highest value of PH (154.4 cm) in cv. Elektra by other treatments. Values of PH by all fungicidal treatments in cv. NK Fair were statistically higher than the values from all plots of cv. Elektra.



1. control (untreated), **2.**Toprex ($Top_{0.5}$), **3.** $Top_{0.5}$ + Ortiva, **4.** $Top_{0.35}$ + Ortiva, **5.** $Top_{0.35}$ + Moddus + Ortiva, **6.** Ortiva, **7.** Folicur + Proline, **8.** Caramba + Cantus

Figure 17: Interactive effect of fungicides and cultivars on plant height (cm) of winter rapeseed at BBCH 80 ± SD in Giessen 2007-08

Lodging

Fungicidal treatments reduced lodging clearly compared with untreated control (Table 10). Alone application of Toprex and Ortiva increased the rate of lodging over other fungicidal treatments. Minimum lodging (3.3) was recorded from those plots which were treated with growth regulator Moddus in combination with $Top_{0.35}$ + Ortiva than that of all other treatments. This treatment produced healthy plants which resist against lodging. Maximum lodging (5.3) was recorded from untreated plots, which was followed by alone application of Ortiva (4.6) and $Toprex_{0.35}$ + Ortiva (4.5) and these were higher than that of all other fungicidal treatments. Combined application of triazole fungicides (Folicur + Proline) and combination of Caramba with Cantus also gave better control of lodging over control and alone application of Ortiva and Toprex. Risk of lodging was reduced by application of fungicides with double applied treatments over single applied and control treatments. Cv. Elektra was more susceptible to lodging than cv. NK Fair.

Number of seeds and pods per main stem

Maximum number of seeds (1172) and pods (60.7) per main stem were produced by application of Ortiva + Cantus, while application of $Top_{0.35}$ + Ortiva reduced seeds and pods on main stem compared with all other treatments (Table 11). Cultivars showed significant differences in the number of seeds and pods per main stem. Cv. Elektra exhibited significantly higher number of seeds (1241) and pods (59.7) per main stem compared with cv. NK Fair (965 and 57.1). There was no interaction between fungicides and cultivars for number of seeds and pods per main stem of winter rapeseed during this experiment.

Table 11: Effect of fungicides and growth regulator on number of seeds and pods per main stem, TGW and seed yield of two cultivars of rapeseed at Giessen 2007-08

Treatments	Seeds/stem	Pods/stem	TGW g	Seed yield dt/ha
Control	1065	57.6	4.48 b	52.0 d
Toprex ($Top_{0.5}$)	1150	60.3	4.59 ab	57.5 bc
$Top_{0.5}$ + Ortiva	1098	60.0	4.71 a	62.1 a
$Top_{0.35}$ + Ortiva	1011	55.0	4.63 a	57.9 b
$Top_{0.35}$ + Moddus + Ortiva	1132	58.7	4.71 a	59.3 ab
Ortiva	1125	57.5	4.61 a	55.1 cd
Folicur + Proline	1072	56.4	4.67 a	57.6 bc
Caramba + Cantus	1172	60.7	4.60 ab	62.1 a
Fun. ($LSD_{0.05}$)	**ns**	**ns**	**0.12**	**3.60**
NK Fair	965 b	57.1 b	4.46 b	58.0
Elektra	1241 a	59.7 a	4.79 a	57.9
Cv. ($LSD_{0.05}$)	**72.8**	**2.3**	**0.06**	**ns**
Fun. x Cv. ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**ns**

TGW

All fungicidal treatments except control gave statistical comparable values of TGW (Table 11). Highest value of TGW (4.71 g) was produced by application of $Top_{0.05}$ + Ortiva and inclusion of growth regulator Moddus in the mixture of $Top_{0.35}$ + Ortiva, while control treatment led to lowest value of TGW (4.48 g). Minor reduction in the value of TGW was observed by alone application of Toprex in comparison with its application in combination with Ortiva. Cultivars showed significant variation in the value of TGW. Cv. Elektra gave highest value of TGW (4.79 g) compared with TGW value (4.46 g) of cv. NK Fair. Interaction between fungicides and cultivar was was found to be non significant regarding TGW.

Seed yield

Seed yield was significantly affected by application of fungicides (Table 11). Maximum seed yield was obtained from those treatments which also produced maximum TGW. Significant lowest value of seed yield (52.0 dt/ha) was recorded from Control plots compared with all other fungicidal treatments, while application of $Top_{0.5}$ + Ortiva and Caramba + Cantus gave significantly higher seed yield (62.1 dt/ha) than that of all other fungicidal treatments with the exception of Moddus + $Top_{0.35}$ + Ortiva treated plot. Combined application of Toprex and Ortiva increased seed yield significantly compared with their alone application. Heavy lodged plots which were treated with alone application of Toprex and Ortiva produced lowest seed yield compared with other fungicidal treatments. Significant higher seed yield (57.6 dt/ha) was obtained by application of Folicur + Proline compared with control. Slight increase in seed yield of winter rapeseed was observed with inclusion of growth regulator (Moddus) than that of without its inclusion in the mixture of $Top_{0.35}$ + Ortiva. Seed yield was varied among tested cultivars non significantly. Cv. NK Fair produced more seed yield (58.0 dt/ha) compared with cv. Elektra (57.9 dt/ha). Non significant interaction between fungicide and cultivar was observed for seed yield.

4.1.2 Quality parameters

Oil content

Oil and protein content did not alter significantly by application of fungicides, while cultivars induced significant differences for these parameters (Table 12). Value of oil content ranged from 42.6 to 45.2% during this experiment. Maximum oil accumulation (45.0%) was recorded from the seeds of those plants which were treated with $Top_{0.35}$ + Ortiva, while alone application of Toprex at the rate of 0.5 L/ha led to minimum oil accumulation (43.3%) over other fungicidal treatments. 44.1% oil content was recorded from Caramba + Cantus treated plants, which was highest value compared with all other fungicide treatments with the exception of $Top_{0.35}$ +

Ortiva. Among Toprex included treatments, minimum oil content (43.3%) was recorded in case of alone application of Toprex. Cv. NK Fair markedly increased oil content (45.2%) compared with cv. Elektra (42.6%). Interaction between fungicide and cultivar was observed non significant regarding oil content.

Protein content

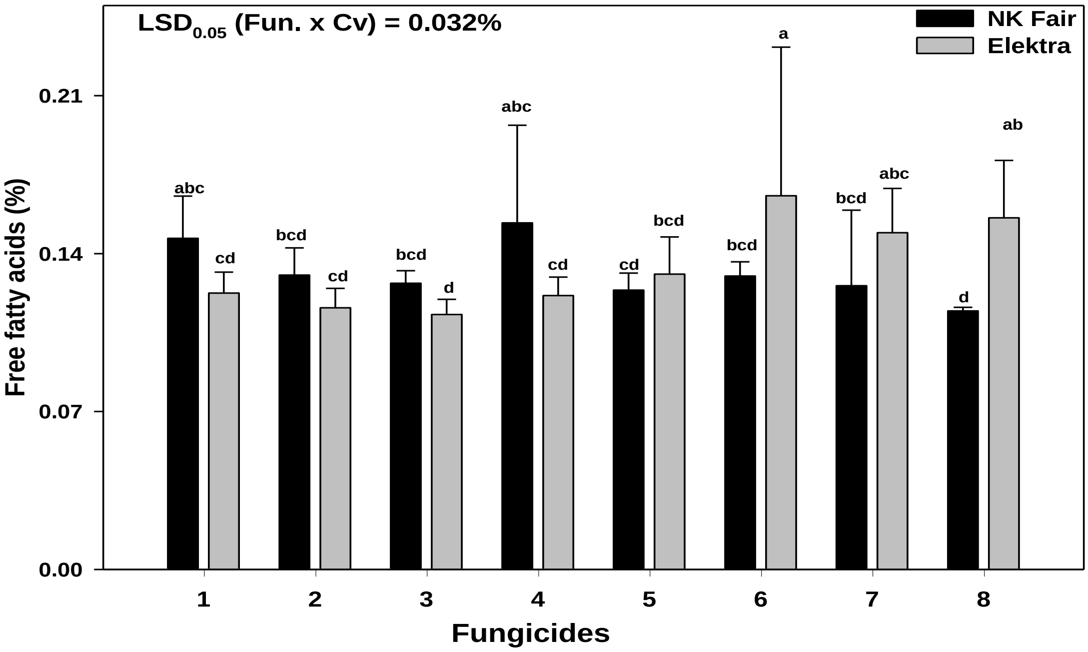
Protein content in the seeds of winter rapeseed ranged from 21.5 to 22.6% among fungicidal treatments (Table 12). Protein content had no significant variations by application of fungicides, whereas cultivars showed significant differences for protein content. $Top_{0.5}$ + Ortiva treated plant accumulate maximum protein content (22.6%) in their seeds which was followed by alone application of $Top_{0.5}$ (22.1%) and Caramba + Cantus (22.0%) compared with other fungicidal treatments. Pronounced increase in the protein content of rapeseed was observed in case of Toprex application at the rate of 0.5 L/ha alone as well as in combination with Ortiva than that of Toprex application at the rate of 0.35 L/ha. Minimum protein content (21.5%) was recorded from the seeds of those plants which were treated with $Top_{0.35}$ + Moddus + Ortiva than that of all other fungicide treatments. Significant higher protein content (22.7%) was exhibited by cv. NK Fair than that of cv. Elektra (21.1%). Non significant interaction was observed between fungicides and cultivars for protein content of rapeseed.

Table 12: Effect of fungicides and growth regulator on quality parameters (oil, protein content, FFA and PV) of two cultivars of rapeseed at Giessen 2007-08

Treatments	Oil %	Protein %	FFA %	PV meq/kg
Control	43.5	21.8	0.14	3.18 b
Toprex ($Top_{0.5}$)	43.3	22.1	0.12	3.54 a
$Top_{0.5}$ + Ortiva	43.9	22.6	0.12	2.61 c
$Top_{0.35}$ + Ortiva	45.0	21.7	0.14	2.31 d
$Top_{0.35}$ + Moddus + Ortiva	43.9	21.5	0.13	2.36 d
Ortiva	43.7	21.9	0.15	2.50 cd
Folicur + Proline	43.6	21.8	0.14	2.26 d
Caramba + Cantus	44.1	22.0	0.14	2.39 cd
Fun. ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**0.24**
NK Fair	45.2 a	22.7 a	0.13	2.84
Elektra	42.6 b	21.1 b	0.13	2.45
Cv. ($LSD_{0.05}$)	**0.73**	**0.70**	**ns**	**0.12**
Fun. x Cv. ($LSD_{0.05}$)	**ns**	**ns**	**0.032**	**0.34**

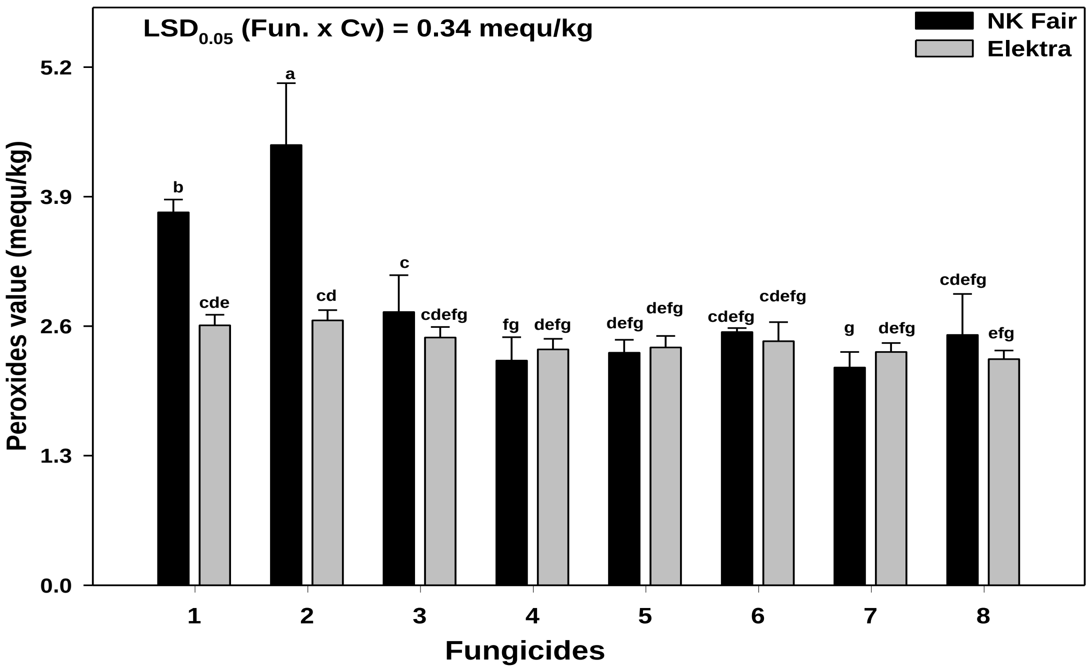
Free fatty acids (FFA)

Table 12 shows that concentration of FFA in the oil of rapeseed was not affected significantly by application of fungicides and among cultivars.



1. control (untreated), **2.**Toprex ($Top_{0.5}$), **3.** $Top_{0.5}$ + Ortiva, **4.** $Top_{0.35}$ + Ortiva,
5. $Top_{0.35}$ + Moddus + Ortiva, **6.** Ortiva, **7.** Folicur + Proline, **8.** Caramba + Cantus

Figure 18: Interactive effect of fungicides and cultivars on the concentration of free fatty acids (%) in the oil of winter rapeseed ± SD at Giessen 2007-08



1. control (untreated), **2.**Toprex ($Top_{0.5}$), **3.** $Top_{0.5}$ + Ortiva, **4.** $Top_{0.35}$ + Ortiva,
5. $Top_{0.35}$ + Moddus + Ortiva, **6.** Ortiva, **7.** Folicur + Proline, **8.** Caramba + Cantus

Figure 19: Interactive effect of fungicides and cultivars on peroxides value (meq/kg) in the oil of winter rapeseed ± SD at Giessen 2007-08

Concentration of FFA ranged from 0.12 to 0.15% among treatments during this experiment. Maximum concentration of FFA (0.15%) was recorded from those plots which were treated with Ortiva alone. Concentration of FFA in the oil of rapeseed had direct relation with rate of lodging. Those plots which were heavily lodged near to maturity had maximum concentration of FFA in the oil. Application of Moddus in combination with $Top_{0.5}$ + Ortiva gave best control against lodging, which was the result to obtain lower concentration of FFA from oil samples of these lower lodged plots than that of Ortiva, control, $Top_{0.35}$ + Ortiva, Folicur + Proline and Caramba + Cantus treated plots. Toprex application at the rate of 0.5 L/ha alone as well as in combination with Ortiva reduced the concentration of FFA to its minimum level (0.12%) compared with other fungicidal treatments. There was no difference in the concentration of FFA among the cultivars during this experiment. There was significant interaction between fungicides and cultivars regarding the concentration of FFA in the oil of rapeseed (Fig. 18).

Peroxide value (PV)

Application of fungicides changed the value of peroxides (PV) in the oil of rapeseed significantly (Table 12). Alone application of $Top_{0.5}$ gave highest concentration of PV (3.54 meq/kg) and was followed by control (3.18 meq/kg) which were statistically differed among each other but higher compared with all other fungicidal treatments. Application of Folicur + Proline led to minimum concentration of PV (2.26 meq/kg) which was statistically lower than that of $Top_{0.5}$, control and $Top_{0.5}$ + Ortiva, while it was statistically same compared with all other fungicidal treatments. Concentration of PV was significantly varied among tested cultivars. Cv. NK Fair exhibited higher PV (2.84 meq/kg) over cv. Elektra (2.45 meq/kg). Interaction between fungicides and cultivars was recorded significant for the concentration of PV in the oil of rapeseed (Fig. 19). In cv. NK Fair application of $Top_{0.5}$ gave maximum value of PV (2.34 meq/kg) which was significantly higher than that of all other fungicide treatments, while application of Caramba + Cantus improved the quality of oil by decreasing PV its minimal level (2.19 meq/kg).

Saturated fatty acids

Saturated fatty acids (palmitic and stearic acid) altered significantly by the application of fungicides (Table 13). Application of $Top_{0.35}$ + Ortiva with and without inclusion of growth regulator Moddus decreased the concentration of palmitic acid significantly than that of all other fungicidal treatments. Alone application of Ortiva and $Top_{0.5}$ led to maximal concentration of palmitic acid which were significantly lower than that of $Top_{0.35}$ included treatments, while these were statistically at par with that of all other fungicidal treatments. By reducing the dose of Toprex from 0.5 to 0.35 L/ha was responsible to decrease the concentration of palmitic acid in the oil during this experiment. Concentration of palmitic acid did not affect significantly among cultivars. Significant interaction between fungicides and cultivars was observed for palmitic acid.

Table 13: Effect of fungicides and growth regulator on the concentration of fatty acids in the oil of two cultivars of rapeseed at Giessen 2007-08

Treatments	C16:0[1)]	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1
Control	4.91 a	1.62 ab	61.3	19.5 ab	9.42 b	0.67	1.35
Toprex ($Top_{0.5}$)	4.95 a	1.59 b	60.3	19.6 a	9.80 a	0.66	1.32
$Top_{0.5}$ + Ortiva	4.93 a	1.62 ab	60.9	19.3 abc	9.55 ab	0.64	1.33
$Top_{0.35}$ + Ortiva	4.54 b	1.61 b	61.6	18.7 d	9.52 ab	0.64	1.32
$Top_{0.35}$ + Mo + Ort.	4.57 b	1.61 b	61.1	19.0 bcd	9.50 b	0.64	1.29
Ortiva	4.95 a	1.67 a	61.3	18.7 d	9.26 b	0.64	1.27
Folicur + Proline	4.83 a	1.65 a	60.7	18.9 cd	9.36 b	0.66	1.31
Caramba + Cantus	4.89 a	1.65 a	61.0	18.8 cd	9.42 b	0.64	1.28
Fun. ($LSD_{0.05}$)	**0.19**	**0.05**	**ns**	**0.49**	**0.29**	**ns**	**ns**
NK Fair	4.83	1.58 b	62.4 a	18.5	9.26 b	0.64	1.35 a
Elektra	4.82	1.68 a	59.7 b	19.6	9.70 a	0.65	1.27 b
Cv. ($LSD_{0.05}$)	**ns**	**0.03**	**0.54**	**0.25**	**0.15**	**ns**	**0.03**
Fun. x Cv. ($LSD_{0.05}$)	**0.28**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

[1)] C16:0 = Palmitic acid, C18:0 = Stearic acid, C18:1 = Oleic acid, C18:2 = Linoleic acid, C18:3 = Linolenic acid, C20:0 = Eicosanoic acid, C20:1n-9 = Eicosenoic acid, Mo = Moddus, Ort = Ortiva

Minimum concentration of stearic acid (1.59%) recorded by the alone application of $Top_{0.5}$ which was statistically lower than that of Ortiva alone, Folicur + Proline and Caramba + Cantus but statistically same with other fungicidal treatments (Table 13). Alone application of Ortiva increased the concentration of stearic acid than that of combined application with Toprex. Cv. NK Fair was exhibited statistically lower concentration of stearic acid (1.58%) compared with cv. Elektra (1.68%). Non significant interaction between fungicides and cultivars was observed for stearic acid.

Unsaturated fatty acids

Oleic acid is the major unsaturated fatty acid of rapeseed oil which was not affected significantly by application of fungicides (Table 13). Value of oleic acid ranged from 58.1 to 64.2% in the oil of rapeseed during this experiment. Maximum concentration of oleic acid (61.9%) was recorded by application of $Top_{0.5}$ + Ortiva, while Caramba + Cantus application led to minimum concentration of oleic acid (61.0%) in rapeseed oil by other fungicidal treatments. Cultivars showed significant variations regarding oleic acid. Higher concentration of Oleic acid (62.4%) was noticed in the oil samples of cv. NK Fair compared with cv. Elektra (59.7%). There was no interaction between fungicides and cultivars for oleic acid.

Linoleic and linolenic acid which are also important unsaturated fatty acids of rapeseed oil were showed significant differences by application of fungicides (Table

13). Maximum concentration of linoleic acid (19.6%) was recorded by alone application of $Top_{0.5}$ which was statistically at par with Control and $Top_{0.5}$ + Ortiva, while it was significantly higher than that of other fungicidal treatments. Application of Ortiva alone as well as in combination with $Top_{0.35}$ gave lowest concentration of linoleic acid (18.7%) in rapeseed oil which was significantly lower than control and $Top_{0.5}$ alone as well as in combination with Ortiva, while it was statistically same with other fungicide treatments. Cv Elektra exhibited significant higher concentration of linoleic acid (19.6%) compared with cv. NK Fair (18.5%). Alone application of $Top_{0.5}$ produced maximum concentration of linolenic acid (9.80%) in rapeseed oil which was statistically same by combined application of Ortiva with $Top_{0.5}$ and $Top_{0.35}$, whilst it was significantly higher than other fungicidal treatments. Concentration of linolenic acid (9.70%) in the oil of cv. Elektra was significantly higher than that of cv. NK Fair (9.26%). Concentration eicosenoic acid was not affected significantly by fungicides. Cv. NK Fair exhibited significant higher concentration of eicosenoic acid (1.35%) compared with cv. Elektra (1.27%). Non significant interaction of fungicides x cultivars was observed for linoleic, linolenic and eicosenoic acid.

4.2 Fungicide × Cultivar Experiment at Rauischholzhausen 2007-08

4.2.1 Field parameters

Lodging

Intensive rate of lodging was recorded in RH due to heavy storm near to maturity (Table 14). Maximum lodging (6.9) was observed from those plots which were treated by Ortiva alone and was followed by $Top_{0.35}$ + Moddus + Ortiva treatment (6.0), while Folicur + Proline treated plots exhibited lower rate of lodging (4.8) compared with other fungicidal treatments. $Top_{0.35}$ + Ortiva and control plots were also heavily lodged (5.8) which were followed by $Top_{0.5}$ treated plots (5.1). Like in Giessen experimental station, here in RH also cv. Elektra was more susceptible to lodging than that of cv. NK Fair. Cv. Elektra was lodged at the rate of 6.6, while 4.4 degree of lodging was recorded from plots of cv. NK Fair.

Plant height

Plant height (PH) was significantly affected by application of fungicides at BBCH 80 of rapeseed (Table 14). Value of PH had inverse relation with the intensity of lodging. Application of Folicur + Proline led to maximum value of PH (125.4 cm) which was significantly higher than that of other fungicidal treatments while it was statistically comparable with the PH of Caramba + Cantus and $Top_{0.5}$ + Ortiva treated plots. Heavily lodged plots which were treated by Ortiva also had lowest value of PH (97.9 cm) which was significantly lower than PH of Folicur + Proline, Caramba + Cantus and $Top_{0.35}$ + Ortiva treated plots, while it was statistically same with other fungicide treatments including control. Significant difference was observed among cultivars for PH. As cv. Elektra was heavily lodged and consequently exhibited lower PH (93.4 cm) in comparison with the PH (125.3 cm) of cv. NK Fair. Non significant interaction between fungicides and cultivars was observed for PH.

Table 14: Effect of fungicides and growth regulator on lodging, plant height (PH), TGW and seed yield of two cultivars of rapeseed at RH 2007-08

Treatments	Lodging (1-9)	Plant height (cm)	TGW (g)	Seed yield (dt/ha)
Control	5.8	100.3 cd	3.77 d	53.9
Toprex ($Top_{0.5}$)	5.1	104.2 cd	3.89 cd	53.9
$Top_{0.5}$ + Ortiva	5.8	105.6 bcd	4.11 abc	55.5
$Top_{0.35}$ + Ortiva	4.9	115.7 abc	4.08 abc	58.2
$Top_{0.35}$ + Moddus + Ortiva	6.0	108.6 bcd	3.92 cd	54.3
Ortiva	6.9	97.9 d	3.95 bcd	56.5
Folicur + Proline	4.8	125.4 a	4.17 ab	57.2
Caramba + Cantus	4.9	121.8 ab	4.26 a	58.0
Fun. ($LSD_{0.05}$)	**-**	**14.6**	**0.22**	**ns**
NK Fair	4.4	125.3 a	3.73 b	53.8 b
Elektra	6.6	93.4 b	4.31 a	58.1 a
Cv. ($LSD_{0.05}$)	**-**	**7.28**	**0.11**	**0.54**
Fun. x Cv. ($LSD_{0.05}$)	**-**	**ns**	**ns**	**ns**

TGW

Application of fungicides showed significant effects on TGW of rapeseed (Table 14). Those plots which resist to lodging gave maximum values of TGW. Maximum value of TGW (4.26 g) was noted from those plots which were treated with Caramba + Cantus and was statistically at par with Folicur + Proline and combination of Ortiva with $Top_{0.5}$ as well as with $Top_{0.35}$, while significantly higher than that of all other fungicide treatments. Seeds of untreated plants exhibited lowest value of TGW (3.77 g) which was statistically comparable with the TGW of $Top_{0.5}$, Ortiva and $Top_{0.35}$ + Moddus + Ortiva treated plots, whereas it was significantly lower than all other fungicidal treatments. Cv. Elektra led to significantly higher value of TGW (4.31 g) in comparison with TGW (3.73 g) of cv. NK Fair. Interaction of fungicides x cultivars was observed non significant regarding TGW.

Seed yield

Seed yield had no significant differences by application of fungicides in RH 2008 (Table 14). Minimum seed yield (53.9 dt/ha) was recorded in case of alone application of $Top_{0.5}$ and control treatment over all other fungicidal treatments., application of $Top_{0.35}$ + Ortiva led to maximum seed yield (58.2 dt/ha) which was followed by Caramba + Cantus (58.0 dt/ha) and Folicur + Proline (57.2 dt/ha) and these were higher han that of all other fungicidal treatments. Seed yield was reduced with inclusion of Moddus in $Top_{0.35}$ + Ortiva. Alone application of $Top_{0.5}$ gave lower seed yield (53.9 dt/ha) compared with its application in combination with Ortiva (55.5 dt/ha). Seed yield was altered significantly among tested cultivars. Cv. Elektra which gave higher TGW also exhibited more seed yield (58.1 dt/ha) compared with cv. NK Fair (53.8 dt/ha). Interaction between fungicides and cultivars was found to be non significant in case of seed yield.

4.2.2 Quality Parameters

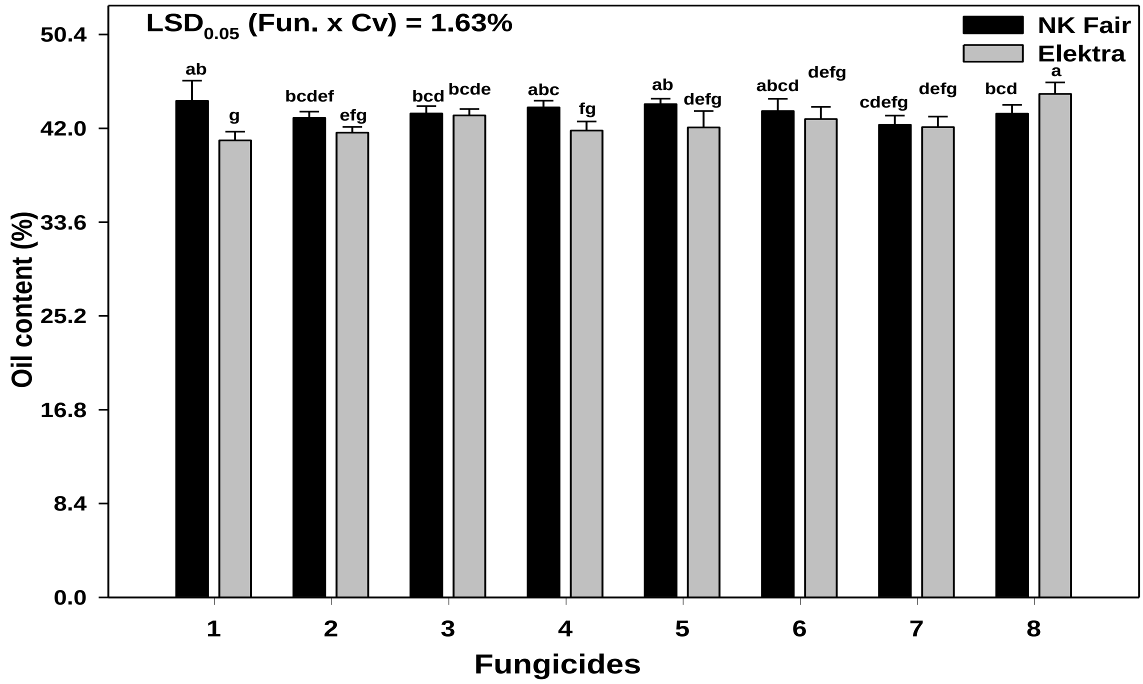
Oil content

Oil content of rapeseed varied significantly by application of fungicides (Table 15). Maximum oil content (44.1%) was recorded from the seeds of those plants which were treated by Caramba + Cantus, which was statistically at par and followed by $Top_{0.5}$ + Ortiva (43.2%), Ortiva (43.2%) and $Top_{0.35}$ + Moddus + Ortiva (43.1%), and it was significantly higher than that of all other fungicidal treatments. Fungicidal treatment Folicur + Proline led to minimal oil content in the seeds of rapeseed which was statistically lower than Caramba + Cantus, while it was statistically similar with that of all other fungicide treatments. Cv. NK Fair accumulated significantly higher oil content (43.5%) over cv. Elektra (42.5%).

Table 15: Effect of fungicides and growth regulator on quality parameters (oil content, protein content, FFA and PV) of two cultivars of rapeseed at RH 2008

Treatments	Oil (%)	Protein (%)	FFA (%)	PV (meq/kg)
Control	42.7 b	22.2 c	0.15 ab	2.46 a
Toprex ($Top_{0.5}$)	42.3 b	23.1 ab	0.15 ab	2.34 bc
$Top_{0.5}$ + Ortiva	43.2 ab	22.9 bc	0.15 ab	2.44 ab
$Top_{0.35}$ + Ortiva	42.8 b	22.9 bc	0.14 b	2.50 a
$Top_{0.35}$ + Moddus + Ortiva	43.1 ab	23.9 a	0.15 ab	2.10 e
Ortiva	43.2 ab	24.1 a	0.16 a	2.43 ab
Folicur + Proline	42.2 b	23.9 a	0.15 ab	2.26 cd
Caramba + Cantus	44.2 a	22.8 bc	0.15 ab	2.22 d
Fun. ($LSD_{0.05}$)	**1.16**	**0.93**	**0.01**	**0.11**
NK Fair	43.5 a	24.1 a	0.14 b	2.19 b
Elektra	42.5 b	22.1 b	0.16 a	2.49 a
Cv. ($LSD_{0.05}$)	**0.58**	**0.47**	**0.01**	**0.05**
Fun. x Cv. ($LSD_{0.05}$)	**1.63**	**1.32**	**0.01**	**ns**

The interaction between fungicides and cultivars was significant regarding oil content (Fig. 20). Maximum oil content was recorded in case of application of Caramba + Cantus in cv. Elektra which was statistically at par with control and inclusion of Ortiva in $Top_{0.5}$ as well as with $Top_{0.35}$ + Moddus in cv. NK Fair, while it was significantly higher than all other fungicidal treatments in both cultivars. Seeds of untreated plants in cv. Elektra exhibited minimum oil content which was significantly lower than that of all fungicidal treatments with the exception of Folicur + Proline in cv. NK Fair.

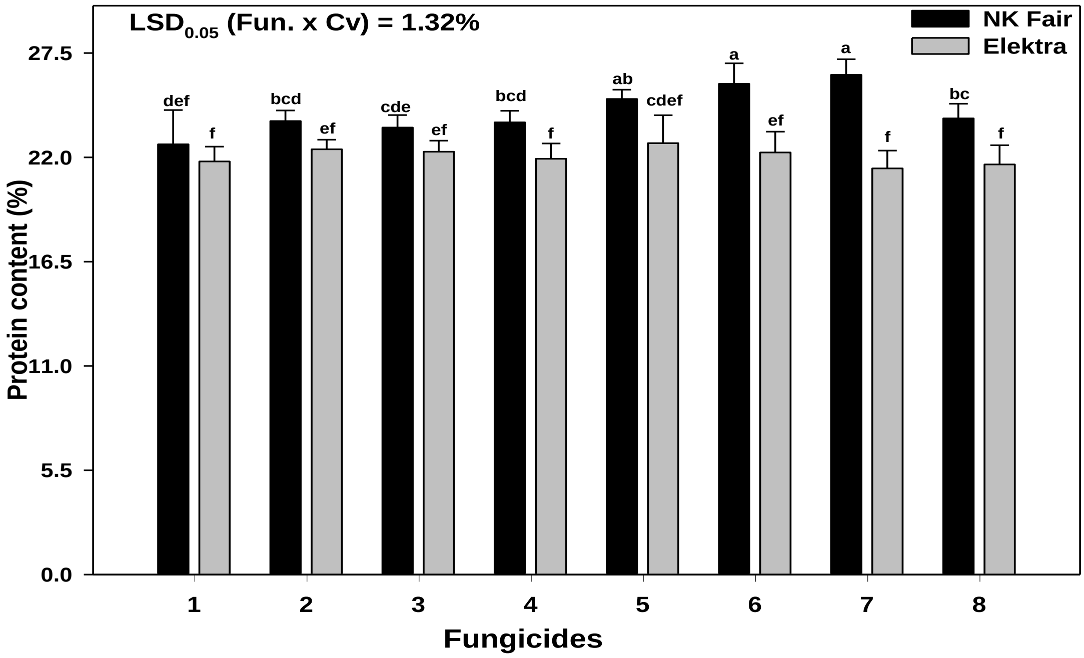


1. control (untreated), **2.**Toprex ($Top_{0.5}$), **3.** $Top_{0.5}$ + Ortiva, **4.** $Top_{0.35}$ + Ortiva, **5.** $Top_{0.35}$ + Moddus + Ortiva, **6.** Ortiva, **7.** Folicur + Proline, **8.** Caramba + Cantus

Figure 20: Interactive effect of fungicides and cultivars on oil content (%) in the seeds of winter rapeseed ± SD at RH 2007-08

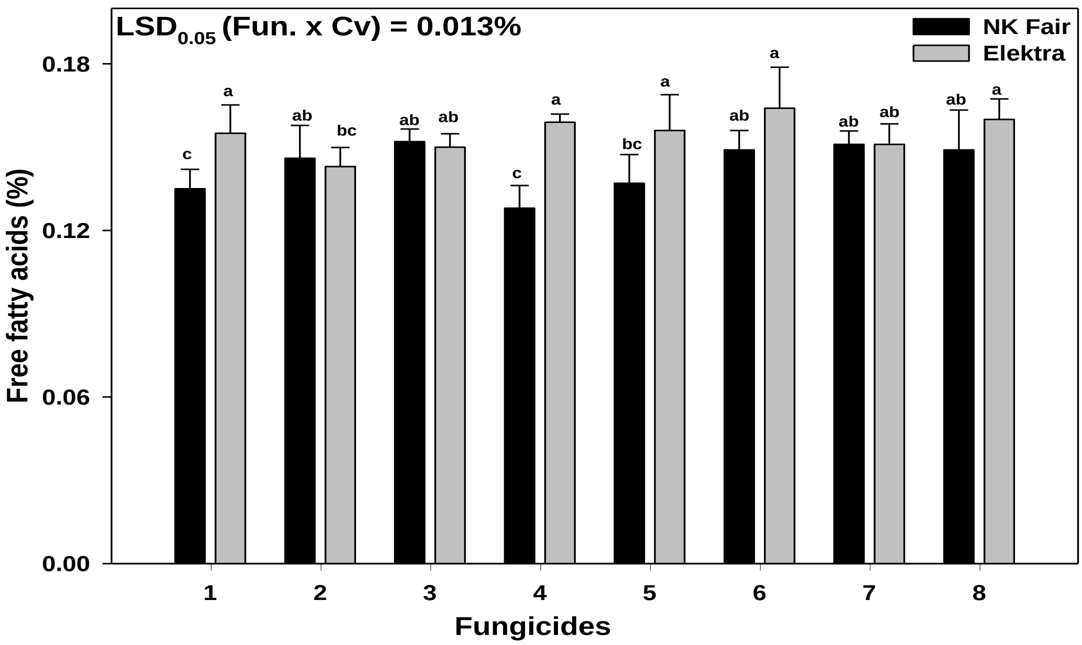
Protein content

Fungicides and cultivars altered the content of protein in the seeds of rapeseed significantly during this experiment (Table 15). Alone application of Ortiva induced maximal protein content (24.1%), followed with $Top_{0.35}$ + Moddus + Ortiva (23.9%) and Folicur + Proline (23.9%) which were all statistically at par with $Top_{0.5}$ alone application (23.1%), while these were significantly higher than that of all other fungicidal treatments. Untreated plots exhibited lower protein content (22.2%) which was statistically comparable with the inclusion of Ortiva in $Top_{0.5}$ (22.9%) as well as in $Top_{0.35}$ (22.9%) and Caramba + Cantus (22.8%) while it was significantly lower than other fungicidal treatments. Protein content was markedly altered among the cultivars. Higher protein content was exhibited by cv. NK Fair (24.1%) over cv. Elektra (22.1%). Interaction between fungicides and cultivars was significant for protein content. Maximum protein content was recorded from those plots which were treated with Folicur + Proline and Ortiva alone application in cv. NK Fair which were at par with mixture of $Top_{0.35}$ + Moddus + Ortiva in cv. NK Fair and were statistically higher than all other treatments in both cultivars. Interaction between fungicides and cultivar was significant for protein content (Fig. 21).



1. control (untreated), **2.**Toprex ($Top_{0.5}$), **3.** $Top_{0.5}$ + Ortiva, **4.** $Top_{0.35}$ + Ortiva,
5. $Top_{0.35}$ + Moddus + Ortiva, **6.** Ortiva, **7.** Folicur + Proline, **8.** Caramba + Cantus

Figure 21: Interactive effect of fungicide and cultivars on protein content (%) in the seeds of winter rapeseed ± SD at RH 2007-08



1. control (untreated), **2.**Toprex ($Top_{0.5}$), **3.** $Top_{0.5}$ + Ortiva, **4.** $Top_{0.35}$ + Ortiva,
5. $Top_{0.35}$ + Moddus + Ortiva, **6.** Ortiva, **7.** Folicur + Proline, **8.** Caramba + Cantus

Figure 22: Interactive effect of fungicides and cultivars on the concentration of free fatty acids (%) in the oil of winter rapeseed ± SD at RH 2007-08

Free fatty acids (FFA)

Fungicides altered the concentration of FFA in the oil of rapeseed significantly and its value ranged from 0.13 to 0.17% during this experiment (Table 15). Alone application of Ortiva induced the concentration of FFA to its maximum level (0.16%) which was significantly higher compared with $Top_{0.35}$ + Ortiva (0.14%) and it was statistically at par with that of all other fungicide treatments. Cultivars showed significant variation regarding FFA. Cv. NK Fair led to minimal value of FFA (0.14%) over cv. Elektra (0.16%). There was significant interaction between fungicides and cultivars for FFA (Fig. 22).

Peroxide value (PV)

Peroxide value (PV) was significantly influenced by the application of fungicides (Table 15). PV (2.50 meq/kg) was recorded by the application of $Top_{0.35}$ + Ortiva which was found to be maximum that was statistically at par and followed with control (2.46 meq/kg), $Top_{0.5}$ + Ortiva (2.44 meq/kg) and alone application of Ortiva (2.43 meq/kg), while it was significantly higher than that of all other fungicidal treatments. Minimum PV (2.10 meq/kg) was found by inclusion of growth regulator Moddus in the mixture of $Top_{0.35}$ + Ortiva which was statistically lower by all other fungicidal treatments. Fungicide treatment Caramba + Moddus gave second lowest value of peroxides (2.22 meq/kg) that was statistically similar with that of Folicur + Proline (2.26 meq/kg), and it was significantly lower than that of all other fungicidal treatments with the exception of $Top_{0.35}$ + Moddus + Ortiva. Significant variations were observed among the cultivars for PV. Cv. Elektra exhibited higher value of PV (2.49 meq/kg) in comparison with cv. NK Fair (2.19 meq/kg). Interaction between fungicides and cultivars was non significant for PV.

Saturated fatty acids

Saturated fatty acids (palmitic and stearic acid) were significantly affected by application of fungicides (Table 16). Minimum concentration of palmitic acid (4.66%) was recorded by application of Caramba + Cantus which was significantly lower than that of all other fungicide treatments. Alone application of $Top_{0.5}$ as well as in combination with Ortiva was also responsible to reduce palmitic acid significantly compared with Folicur + Proline, and alone application of Ortiva as well as its combined application with $Top_{0.35}$ + Moddus, and were statistically at par with control and $Top_{0.5}$ + Ortiva. Significant variations were observed among cultivars for palmitic acid. Cv. NK Fair exhibited higher concentration of palmitic acid (5.06%) over cv. Elektra (4.61%). Interaction between fungicides and cultivars was found to be significant for palmitic acid.

Concentration of stearic acid ranged from 1.46 to 1.64% in the oil of rapeseed during this experiment. Fungicidal treatment Folicur + Proline decreased stearic acid its minimum level (1.47%) which was significantly lower by all other fungicidal treatments. Maximum value of stearic acid (1.58%) was recorded by alone application of $Top_{0.5}$ which was statistically higher than that of alone application of Ortiva (1.50%) as well as its combination with $Top_{0.35}$ + Moddus + Ortiva (1.52%) and Folicur + Proline (1.47%), and was statistically at par with all other fungicide treatments used during this study. Cultivars showed significant variations regarding stearic acid. Higher concentration of stearic acid (1.62%) was noted in the oil of cv. Elektra as compared with cv. NK Fair (1.45%). There was significant interaction between fungicides and cultivars regarding stearic acid. Eicosanoic acid was significantly affected by application of fungicides and among the cultivars. Cv. Elektra exhibited higher eicosanoic acid (0.60%) compared with cv. NK Fair (0.54%). Value of this long chain fatty acid ranged from 0.49 to 0.62% during this experiment. Interaction between fungicides and cultivars was found to be significant regarding eicosanoic acid.

Table 16: Effect of fungicides and growth regulator on the concentration of fatty acids in the oil of two cultivars of rapeseed at RH 2007-08

Treatments	C16:0[1)]	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1
Control	4.87 abc	1.54 abc	59.0	19.8 a	10.00 cd	0.57 b	1.19 cd
Toprex ($Top_{0.5}$)	4.80 c	1.58 a	59.8	19.3 bc	9.70 e	0.61 a	1.28 ab
$Top_{0.5}$ + Ortiva	4.80 c	1.56 ab	60.0	19.2 c	9.84 cde	0.61 a	1.30 a
$Top_{0.35}$ + Ortiva	4.81 bc	1.56 ab	60.1	19.0 c	9.79 de	0.59 ab	1.26 ab
$Top_{0.35}$ + Mo + Ort.	4.88 ab	1.52 bc	59.5	19.1 c	9.78 de	0.58 ab	1.30 a
Ortiva	4.93 a	1.50 c	60.3	19.7 ab	10.35 b	0.53 c	1.17 d
Folicur + Proline	4.94 a	1.47 d	59.9	19.9 a	10.70 a	0.50 c	1.15 d
Caramba + Cantus	4.66 d	1.55 ab	60.8	19.1 c	10.06 bc	0.58 ab	1.24 bc
Fun. ($LSD_{0.05}$)	**0.07**	**0.04**	**ns**	**0.31**	**0.26**	**0.03**	**0.05**
NK Fair	5.06 a	1.45 b	60.1 a	19.3	10.00	0.54 b	1.23
Elektra	4.61 b	1.62 a	59.8 b	19.5	10.10	0.60 a	1.24
Cv. ($LSD_{0.05}$)	**0.04**	**0.02**	**0.54**	**ns**	**ns**	**0.02**	**ns**
Fun. xCv. ($LSD_{0.05}$)	**0.10**	**0.06**	**ns**	**0.45**	**0.37**	**0.04**	**0.08**

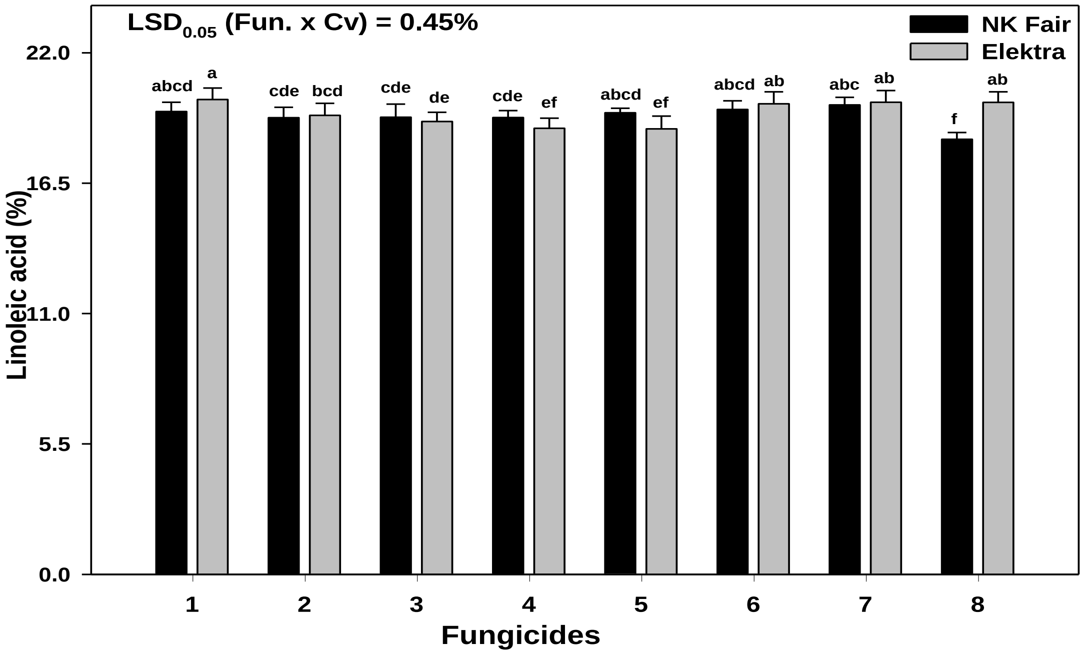
[1)] C16:0 = Palmitic acid, C18:0 = Stearic acid, C18:1 = Oleic acid, C18:2 = Linoleic acid, C18:3 = Linolenic acid, C20:0 = Eicosanoic acid, C20:1n-9 = Eicosenoic acid, Mo = Moddus, Ort = Ortiva

Unsaturated fatty acids

Application of fungicides affected the concentration of linoleic, linolenic and eicosenoic acid significantly (Table 16). Concentration of oleic acid which was not statistically affected by the fungicidal treatments ranged from 58.8 to 61.0% during this experiment. Maximum concentration of oleic acid (60.8%) was recorded in case of Caramba + Cantus which followed by alone application of Ortiva (60.3%), $Top_{0.35}$ + Ortiva (60.1%) and $Top_{0.5}$ + Ortiva (60.0%) among fungicidal treatments. Untreated plots led to minimal value of oleic acid (59.0%) as compared with all other fungicide treatments. Second lowest concentration of oleic acid (59.5%) in the oil of rapeseed was recorded in case of application of $Top_{0.35}$ + Moddus + Ortiva compared with other fungicidal treatments during this experiment. Cultivars showed significant differences regarding oleic acid. Cv. NK Fair exhibited higher value of oleic acid (60.1%) as compared with cv. Elektra (59.8%). Non significant interaction between fungicides and cultivars was observed for oleic acid.

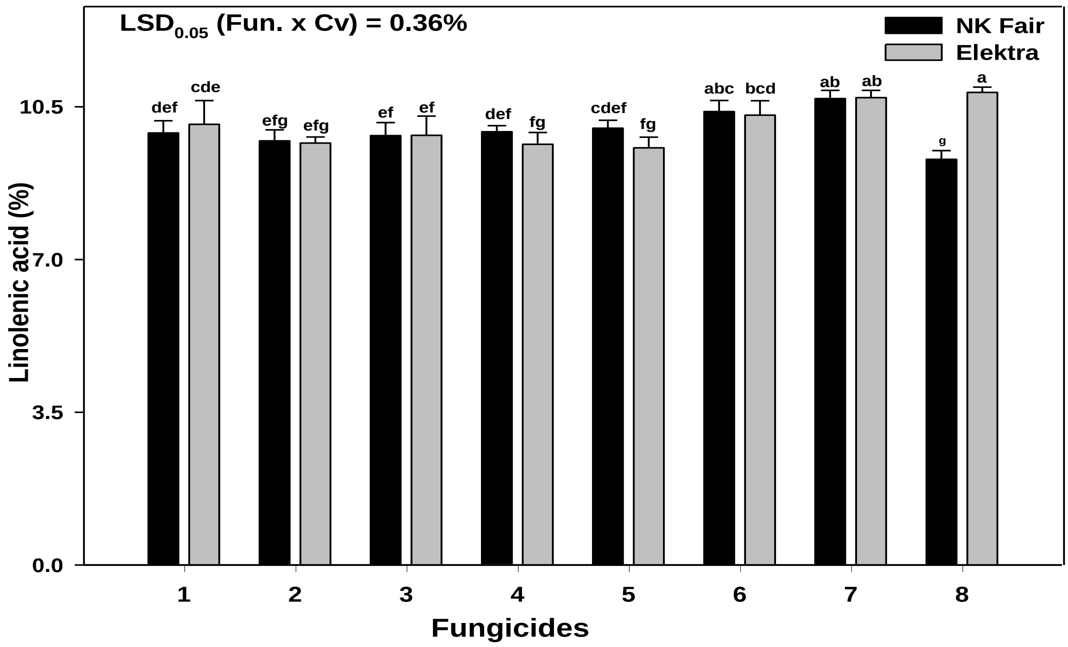
Effect of fungicides was significant for linoleic acid. Folicur + Proline increased the concentration of linoleic acid to its maximum level (19.9%) which was similar and followed by control (19.8%) and alone application of Ortiva (19.7%), while it was significantly higher than that of all other fungicide treatments. Minimum linoleic acid (19.0%) was recorded by application of $Top_{0.35}$ + Ortiva which was significantly lower compared with already mentioned fungicidal treatments which produced higher linoleic acid and it was statistically at par with that of all other fungicidal treatments.
Cultivars did not show significant variation for linoleic acid. Interaction between fungicides and cultivars was observed significant regarding linoleic acid (Fig. 23). Interaction results showed that application of triazole fungicide Toprex had retarding effect on the concentration of linoleic acid whether it was applied alone or in combination with Ortiva and growth regulator Moddus. Maximum concentration of linoleic acid was recorded from untreated plots of cv. Elektra. Effect of Folicur + Proline was considered best to increase the concentration of linoleic acid and linolenic in comparison with other fungicidal treatments for both cultivars.

Linolenic acid influenced significantly by application of fungicides. Value of linolenic acid was varied among 9.60 to 10.90% during this experiment. 10.70% concentration of linolenic acid was the maximum value in case of application of Folicur + Proline which was significantly higher by all other fungicide treatments. Second best value of linolenic acid (10.35%) was recorded in case of Ortiva alone application and it was statistically similar with Caramba + Cantus (10.06%), while it was significantly higher than that of all other fungicide treatments with the exception of Folicur + Proline. Like in case of linoleic acid it was also non significantly affected among the cultivars during this experiment. There was significant interaction of fungicides x cultivars for linolenic acid (Fig. 24). Positive response by the application of triazole group of fungicides (Folicur + Proline) was observed regarding linolenic acid in interaction results. In both cultivars application of Folicur + Proline increased the concentration of linolenic acid significantly compared with all other fungicide treatments, while these were statistically at par with that of Caramba + Cantus in cv. Elektra and alone application of Ortiva in both cultivars. In interaction results application of Caramba + Cantus in cv. NK Fair led to minimum value of linolenic acid (9.30%) that was statistically same with alone application of $Top_{0.5}$ (9.70%) in both cultivars and application of $Top_{0.35}$ + Ortiva with (9.56%) and without growth regulator Moddus (9.64%) in cv. Elektra, while it was significantly lower than that of all other fungicidal treatments in both cultivars.



1. control (untreated), **2.**Toprex ($Top_{0.5}$), **3.** $Top_{0.5}$ + Ortiva, **4.** $Top_{0.35}$ + Ortiva,
5. $Top_{0.35}$ + Moddus + Ortiva, **6.** Ortiva, **7.** Folicur + Proline, **8.** Caramba + Cantus

Figure 23: Interactive effect of fungicides and cultivars on the concentration of linoleic acid (%) in the oil of winter rapeseed ± SD at RH 2007-08



1. control (untreated), **2.**Toprex ($Top_{0.5}$), **3.** $Top_{0.5}$ + Ortiva, **4.** $Top_{0.35}$ + Ortiva,
5. $Top_{0.35}$ + Moddus + Ortiva, **6.** Ortiva, **7.** Folicur + Proline, **8.** Caramba + Cantus

Figure 24: Interactive effect of fungicides and cultivars on the concentration of linolenic acid (%) in the oil of winter rapeseed ± SD at RH 2007-08

Long chain unsaturated fatty acid eicosenoic acid was significantly affected by application of fungicides and its value varied from 1.14 to 1.32% during this experiment. Maximum concentration of eicosenoic acid (1.30%) was recorded in case of application of Ortiva with $Top_{0.5}$ as well as with $Top_{0.35}$ + Moddus and these were statistically same and followed with that of $Top_{0.5}$ alone application (1.28%) and $Top_{0.35}$ + Ortiva (1.26%), while these were statistically higher with that of all other fungicide treatments. Alone application of Ortiva and Folicur + Proline led to minimum values of eicosenoic acid which was statistically same with control, while these were significantly lower than all other fungicide treatments. Cultivars had no significant effect regarding eicosenoic acid. Interaction of fungicides x cultivars was found to be significant for eicosenoic acid.

4.3 Fungicide Experiment at Giessen 2008-09

4.3.1 Field parameters

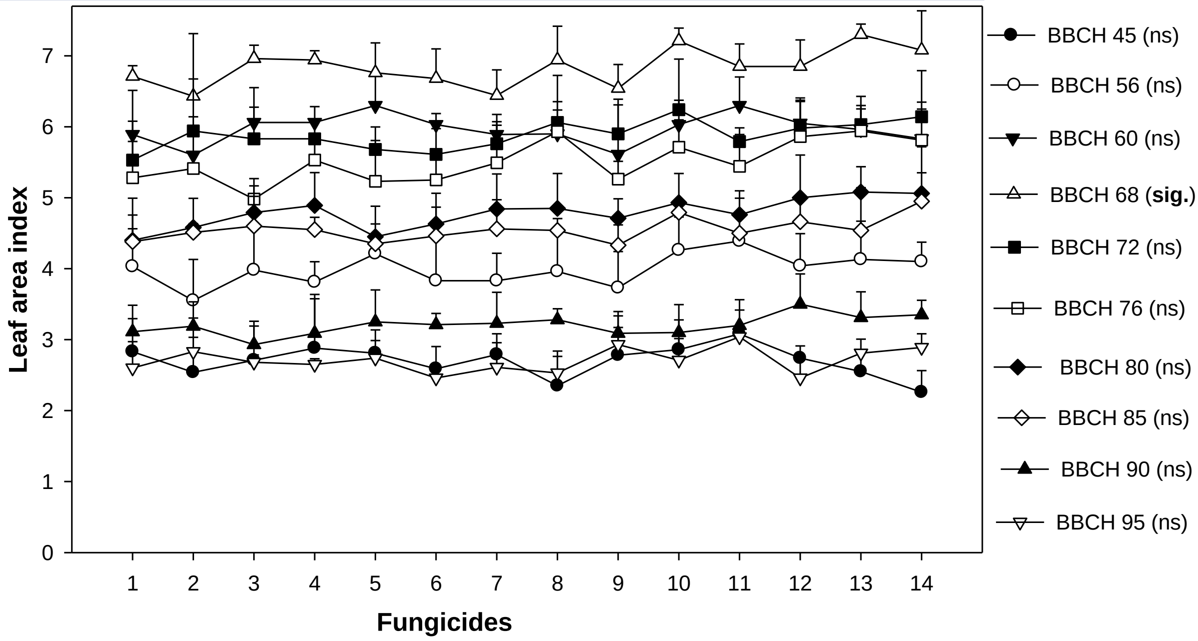
Leaf area index (LAI)

Measurement of LAI was started from BBCH 45 to till maturity with weekly interval during this experiment in Giessen 2009 (Fig. 25). At BBCH 45 before 1st application of fungicides value of LAI was ranged from 2.26 to 2.88 which showed no significant differences among fungicide treatments. LAI was not affected significantly after 3 days of 1st application of fungicides at BBCH 56. Next measurement was made at BBCH 60 just before second application which gave non significant values of LAI. Value of LAI was ranging among 5.60 to 6.30 at BBCH 60. Those plots which were treated with Toprex showed increasing trend of LAI at both BBCH 56 and 60.

After second application of fungicides, next measurement was done at BBCH 68 when rapeseed plant attained its maximum canopy with higher green area. At this stage LAI was altered significantly by application of fungicides during this experiment. Alone application of Folicur led to minimum value of LAI (6.43) that was statistically at par with that of Proline (6.44), Moddus (6.54), Harvesan (6.68), control (6.71), Prosaro 6.76, Toprex (6.85), Toprex + Ortiva (6.85), Moddus + Cantus Gold (6.94) and alone application of Cantus (6.94), While it was significantly lower than that of all other fungicide treatments at BBCH 68. Maximum LAI (7.30) was noted at BBCH 68 from those plots which were treated with Folicur + Ortiva and that value of LAI was significantly higher over alone application of Folicur (6.43), Proline (6.44), Moddus (6.54), Harvesan (6.68), Prosaro (6.76) and control (6.71), while it was statistically similar with that of all other fungicide treatments. A slight increase in LAI was observed from those plots which were treated with strobilurin fungicide (Ortiva) alone or in combination with triazole fungicides at BBCH 68. Non significant differences were recorded for LAI in next all measurements till maturity.

BBCH 68 (**significant**) $LSD_{0.05}$ = 0.59

*Fungi.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
LAI_{BBCH68}	6.71 bcde	6.43 e	6.96 abcd	6.94 abcde	6.76 bcde	6.44 de	6.68 cde	6.94 abcde	6.54 de	7.21 ab	6.85 abcde	6.85 abcde	7.30 a	7.08 abc



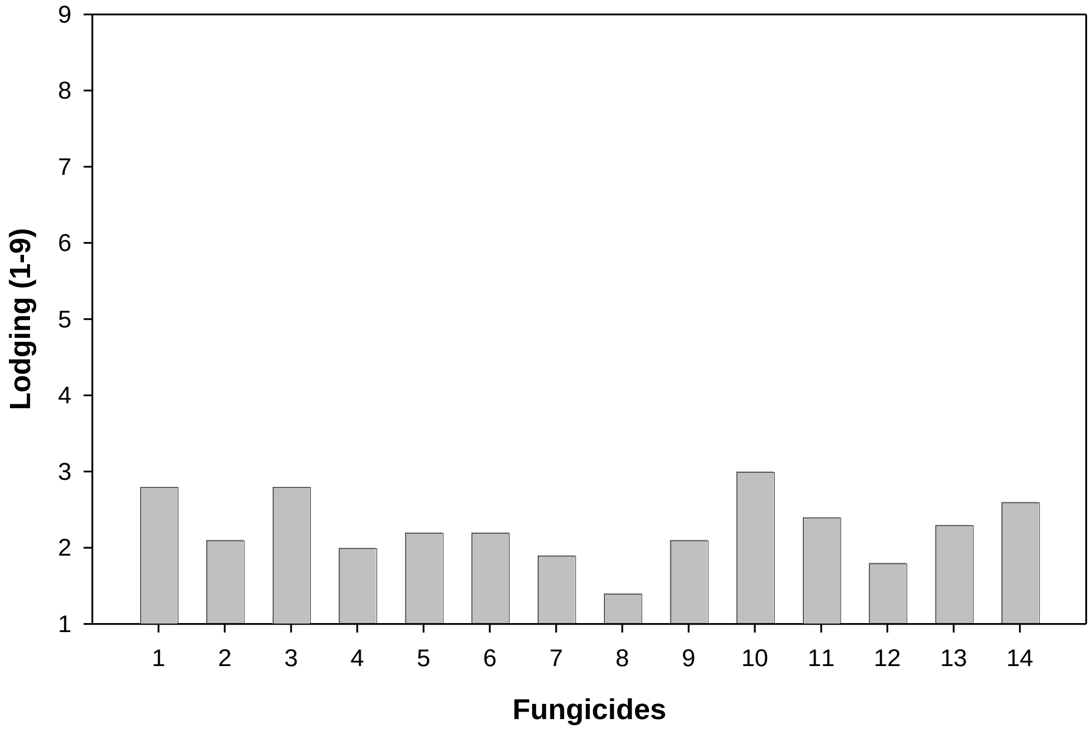
***1.** Control , **2.** Folicur, **3.** Caramba, **4.** Cantus, **5.** Prosaro, **6.** Proline, **7.** Harvesan, **8.** Moddus + Cantus Gold, **9.** Moddus, **10.** Ortiva, **11.** Toprex, **12.** Toprex + Ortiva, **13.** Folicur + Ortiva, **14.** Caramba + Ortiva

Figure 25: Effect of different fungicides on leaf area index of winter rapeseed at different growth stages ± SD at Giessen 2008-09

Maximum LAI (6.24) was recorded by alone application of Ortiva at BBCH 72, while untreated plots gave minimum value of LAI (5.53) at this growth stage by other treatments. Plots which were treated with Folicur + Ortiva exhibited maximum LAI at BBCH 76 and 80 compared with other treatments. At BBCH 80 combined application of Ortiva improved LAI compared to all other treatments including control. Among single treated plots, application of Folicur had adverse effect on LAI of rapeseed at all growth stages of measurement. Double applied plots gave more LAI compared with singly treated plots. At the end stages of rapeseed untreated plots gave minimal value of LAI than that of all other fungicidal treatments, while alone application of Ortiva as well as in combination with other fungicides slightly increased LAI over other fungicide treatments.

Lodging

Rate of lodging was estimated at BBCH 80, and its value ranged from 1.4 to 3.0 during this experiment (Fig. 26). Maximum lodging (3.0) was noted by alone application of Ortiva by other treatments which was followed by control (2.8), Caramba (2.8), Caramba + Ortiva (2.6) and Toprex (2.4). Application of growth regulator Moddus in combination with Cantus Gold gave best control against lodging (1.4) over other treatments. More lodging was recorded from those plots which were treated with Caramba alone as well as in combination with Ortiva during this experiment. Harvesan was the best treatment against lodging, while Caramba and Toprex treated plots like control attained maximum lodging among all single applied treatments. More lodging was recorded in case of alone application of Moddus compared with the combined application of Moddus with Cantus Gold. Likewise combined application of Toprex with Ortiva gave better control against lodging than that of Toprex alone application.



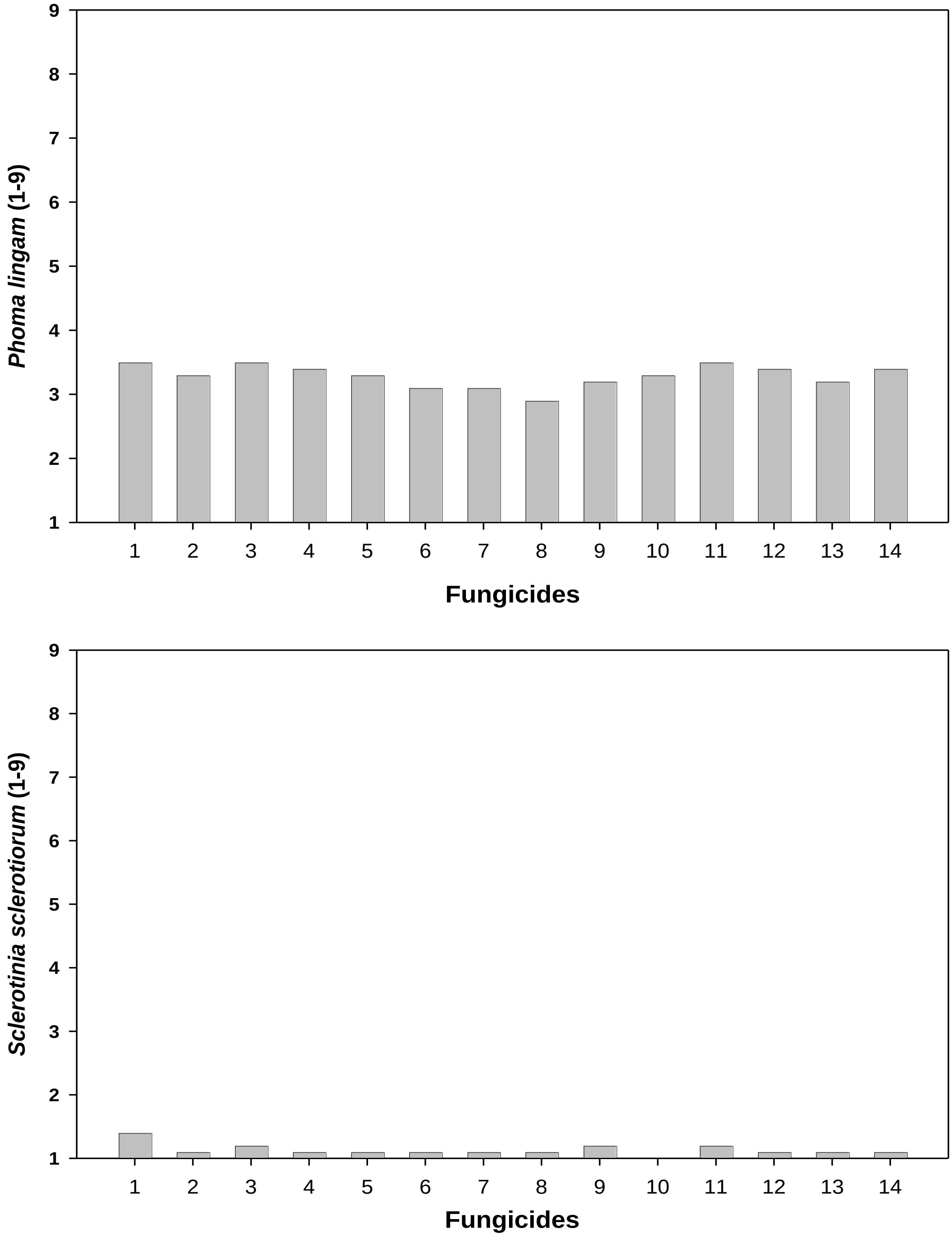
1. Control , **2.** Folicur, **3.** Caramba, **4.** Cantus, **5.** Prosaro, **6.** Proline, **7.** Harvesan, **8.** Moddus + Cantus Gold, **9.** Moddus, **10.** Ortiva, **11.** Toprex, **12.** Toprex + Ortiva, **13.** Folicur + Ortiva, **14.** Caramba + Ortiva

Figure 26: Effect of different fungicides on lodging of winter rapeseed at Giessen 2008-09

Diseases

Incidence of diseases (*Phoma lingam*, *Sclerotenia sclerotiorum*) was not so severe in Giessen 2009 (Fig. 27). The severity of Phoma was ranged from 2.9 to 3.5, while for Sclerotinia value did not exceed to 1.4 during this experiment. Severity of Phoma was not clearly differed among fungicdal treatments. Best control of Phoma (2.9) was recorded by application of Moddus + Cantus Gold over other fungicide treatments. Maximum attack of Phoma (3.5) was obsereved from untreated and Toprex and Caramba alone applied plots compared with that of all other fungicide treatments. Severity of Phoma was reduced its minimum level by application of Proline and Harvesan among all single applied treatments.

During this experiment minimal incidence of sclerotinia was observed compared with Phoma. Maximum severity of Sclerotinia (1.4) was observed from untreated plots by other treatments. There was no symptom of sclerotinia from those plots which were treated with Ortiva alone.



1. Control , **2.** Folicur, **3.** Caramba, **4.** Cantus, **5.** Prosaro, **6.** Proline, **7.** Harvesan, **8.** Moddus + Cantus Gold, **9.** Moddus, **10.** Ortiva, **11.** Toprex, **12.** Toprex + Ortiva, **13.** Folicur + Ortiva, **14.** Caramba + Ortiva

Figure 27: Effect of different fungicides on *Phoma lingam* and *Sclerotinia sclerotiorum* of winter rapeseed at Giessen 2008-09

Seed yield components

Seed yield components did not show significant differences by application of fungicides (Table 17). Application of growth regulator Moddus in combination with strobilurin fungicide (Cantus Gold) improved most of these parameters prominently compared with other treatments. Maximal number of pods per plant (462.9) were noted from Moddus + Cantus Gold treated plants which was followed by alone application of Folicur (344.6), Caramba (337.1) and Prosaro (330.9), while untreated plants attained minimum pods (207.1) over other fungicide treatments. Application of Harvesan reduced number of pods per plant (210.3) which was near to Control. Value of pod length varied from 8.1 to 8.6 cm among the treatments. Application of Moddus in combination with Cantus Gold increased pod length its maximum level 8.6 cm by other treatments.

Table 17: Effect of fungicides and growth regulator on pods/plant (P/Pl), pod length (PL), seeds/pod (S/Pd) and number of main-branches (MB) and sub-branches (SB) per plant of rapeseed at Giessen 2008-09

Treatments	P/Pl	PL (cm)	S/Pd	MB	SB
Control	207.1	8.2	23.3	6.9	3.0
Folicur	344.6	8.5	27.6	8.3	10.9
Caramba	337.1	8.1	24.2	8.1	8.4
Cantus	315.4	8.1	29.3	7.1	7.1
Prosaro	330.9	8.4	27.3	7.8	7.6
Proline	297.4	8.4	26.4	6.8	8.6
Harvesan	210.3	8.3	24.9	6.1	6.1
Moddus + Cantus Gold	462.9	8.6	28.3	8.0	12.9
Moddus	317.6	8.3	25.7	7.3	8.9
Ortiva	305.9	8.1	26.9	7.1	9.6
Toprex	316.1	8.5	27.9	7.3	8.4
Toprex + Ortiva	251.9	8.3	25.2	6.9	7.5
Folicur + Ortiva	220.8	8.5	24.2	6.8	5.8
Caramba +Ortiva	338.5	8.1	27.8	6.3	8.9
$LSD_{0.05}$	ns	ns	ns	ns	ns

Alone application of Caramba, Cantus, Ortiva and combined application of Caramba with Ortiva reduced pod length to its minimum level (8.1 cm) compared with that of all other fungicide treatments. Maximum seeds per pod (29.3) were recorded by alone application of Cantus which was followed by Moddus + Cantus Gold (28.3), Toprex (27.9), Caramba + Ortiva (27.8) and Folicur (27.6), While minimum number of seeds per pod (23.3) were noted from pods of untreated plants over other fungicide treatments. Plants which were treated with Folicur singly exhibited maximum number of main-branches (8.3) which was followed by Caramba (8.1) and Moddus + Cantus Gold (8.0), while alone application of Harvesan reduced main-branches its minimum level (6.1) by other treatments. Moddus + Cantus Gold led to maximum number of sub-branches per plant (12.9) and were followed by Folicur (10.9) and Ortiva (9.6), whereas untreated plants exhibited lowest number of sub-branches (3.0) over other treatments.

Plant height (PH)

PH did not alter significantly by application of fungicides at BBCH 80 (Table 18). Value of PH was ranged from 137.3 to 142.9 cm during this experiment. Maximum PH (142.9 cm) was recorded from Cantus treated plots, that was followed by Ortiva (141.6 cm), Harvesan (141.5 cm), Toprex + Ortiva (141.3 cm) and Folicur (140.6 cm) and it was higher than that of all other fungicide treatments. Minimum plant height (137.3 cm) was recorded by application of Moddus and Caramba + Ortiva which was smaller by other treatments. Among all applied fungicides alone application of Caramba as well as its combination with Ortiva was observed stronger to retard plant height during this experiment.

Table 18: Effect of fungicides and growth regulator on plant height (PH), TGW and seed yield of rapeseed at Giessen 2008-09

Treatments	PH (cm)	TGW (g)	Seed yield (dt/ha)
Control	137.5	5.20 abc	56.7
Folicur	140.6	5.23 ab	56.1
Caramba	137.8	5.04 d	54.5
Cantus	142.9	5.11 bcd	58.9
Prosaro	138.9	5.05 cd	57.6
Proline	139.9	5.04 d	55.8
Harvesan	141.5	5.17 abcd	56.0
Moddus + Cantus Gold	138.8	5.31 a	57.2
Moddus	137.3	5.17 abcd	55.5
Ortiva	141.6	5.14 bcd	58.9
Toprex	139.0	5.15 bcd	56.7
Toprex + Ortiva	141.3	5.21 ab	58.9
Folicur + Ortiva	139.0	5.15 bcd	58.7
Caramba +Ortiva	137.3	5.12 bcd	56.9
$LSD_{0.05}$	**ns**	**0.15**	**ns**

TGW

Application of different fungicides changed the value of TGW significantly (Table 18). Value of TGW was ranged from 5.04 to 5.31 g during this experiment. Application of growth regulator Moddus in combination with Cantus Gold gave maximum value of TGW (5.31 g) which was statistically at par and followed by Folicur (5.23 g), Toprex + Ortiva (5.21 g), control (5.20 g), Harvesan (5.17 g) and Moddus (5.17 g), while it was significantly higher than that of all other treatments. Alone application of Caramba and Proline led to minimum value of TGW (5.04 g) which was significantly lower than that of already mentioned fungicide treatments (Moddus + Cantus Gold, Folicur, Toprex + Ortiva and control) in this paragraph while, these were statistically similar with that of all other fungicide treatments. Strobilurin fungicide (Ortiva) slightly improved TGW when it was applied in combination with Toprex compared with that of its alone and combined application with other fungicides (Folicur and Caramba) but TGW of these Ortiva included treatments were statistically at par among each other.

Seed yield

Seed yield did not alter significantly by application of fungicides during this experiment in Giessen (Table 18). Alone application of Caramba gave least value of seed yield (54.5 dt/ha) by other fungicidal treatments. Alone application of Ortiva and Cantus and combination of Ortiva + Toprex led to maximum seed yield (58.9 dt/ha), which were followed by Folicur +Ortiva (58.7 dt/ha), Prosaro (57.6 dt/ha) and Moddus + Cantus Gold (57.2 dt/ha) and these were higher than that of all other fungicide treatments. 56.7 dt/ha seed yield was obtained from control (untreated) treatment and Toprex alone application, which were followed by Folicur (56.1 dt/ha), Harvesan (56.0 dt/ha), Proline (55.8 dt/ha), Moddus (55.5 dt/ha) and Caramba (54.5 dt/ha), while these were lower than that of all other fungicide treatments. Among fungicidal treatments application of Ortiva alone as well as in combination with other fungicides with the exception of its inclusion in Caramba increased seed yield its maximum level over other fungicidal treatments during this experiment.

4.3.2 Quality parameters

Protein content

Non significant differences were observed regarding protein content by application of fungicides during this experiment (Table 19). Value of protein content was ranged from19.8 to 20.9% during this study. Alone application of Toprex gave minimum value of protein content (19.8%) by other treatments. Maximum protein content (20.9%) was obtained from the seeds of those plants which were treated with Harvesan and was followed by Prosaro (20.7%), Moddus + Cantus Gold (20.5%) and Folicur (20.5%) which were higher than that of all other fungicide treatments. Growth regulator Moddus showed somehow better response to increase protein content with its alone as well as in combined application with Cantus Gold.

Free fatty acids (FFA)

Application of fungicides did not change the concentration FFA in the oil of rapeseed significantly (Table 19). Maximum value of FFA (2.17%) was recorded by application of Proline which was followed by Moddus (2.02%), Cantus (2.05%), Caramba + Ortiva (2.05%) and Harvesan (2.02%), which were higher than that of all other fungicide treatments. Application of Caramba improved the quality of rapeseed oil by reducing concentration of FFA to its minimum level (1.52%) over other fungicide treatments during this experiment. 1.82% FFA was recorded from oil of Control treatment which was higher than that of Caramba (1.52%), Toprex (1.61%), Moddus + Cantus Gold (1.79%) and Prosaro (1.81%), while it was lower than that of all other fungicidal treatments.

Table 19: Effect of fungicides and growth regulator on quality parameters (protein content, FFA and PV) of rapeseed at Giessen 2008-09

Treatments	Protein (%)	FFA (%)	PV (meq/kg)
Control	20.3	1.82	8.43
Folicur	20.5	1.89	8.07
Caramba	20.0	1.52	8.94
Cantus	19.9	2.05	6.69
Prosaro	20.7	1.81	7.72
Proline	20.2	2.17	8.10
Harvesan	20.9	2.02	8.48
Moddus + Cantus Gold	20.5	1.79	8.71
Moddus	20.3	2.09	7.68
Ortiva	20.4	1.85	9.85
Toprex	19.8	1.61	8.49
Toprex + Ortiva	20.2	1.84	9.46
Folicur + Ortiva	20.2	1.89	8.19
Caramba +Ortiva	20.2	2.05	8.47
$LSD_{0.05}$	**ns**	**ns**	**ns**

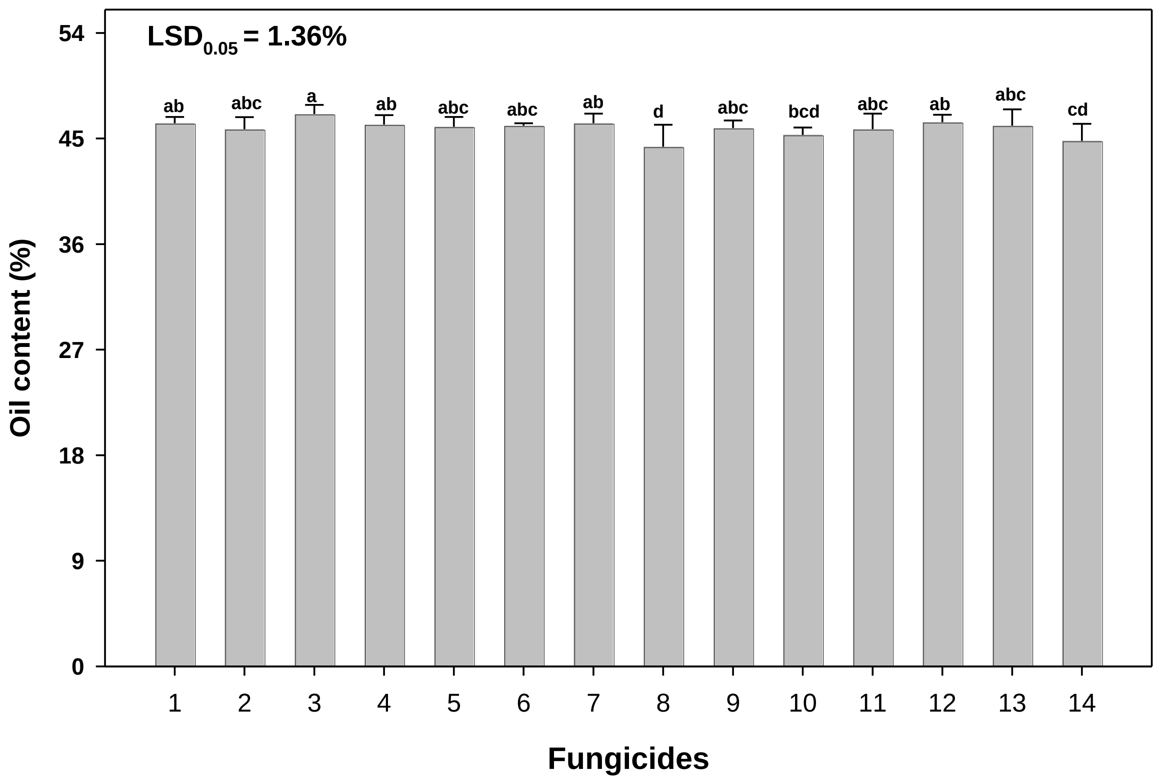
Peroxide value

Peroxides value (PV) had no significant effect by application of fungicides during this experiment (Table 19). Alone application of Ortiva gave maximum value of PV (9.85 meq/kg) which was followed by Toprex + Ortiva (9.46 meq/kg), Caramba (8.94 meq/kg), Moddus + Cantu Gold (8.71 meq/kg) and Toprex (8.49 meq/kg), while these were higher than that of all other fungicide treatments. PV was reduced by applying Cantus its lowest level (6.69 meq/kg) compared with other treatments. Application of

Moddus (7.68 meq/kg) and Prosaro (7.72 meq/kg) also reduced PV by other treatment with the exception of Cantus. Alone application of Moddus decreased PV (12%) compared with its application in combination with Cantus Gold.

Oil content

Oil content was affected significantly by application of fungicides during this study (Fig. 28).



1. Control , **2.** Folicur, **3.** Caramba, **4.** Cantus, **5.** Prosaro, **6.** Proline, **7.** Harvesan, **8.** Moddus + Cantus Gold, **9.** Moddus, **10.** Ortiva, **11.** Toprex, **12.** Toprex + Ortiva, **13.** Folicur + Ortiva, **14.** Caramba + Ortiva

Figure 28: Effect of different fungicides and growth regulator on oil content of winter rapeseed ± SD in Giessen 2008-09

Value of oil content ranged from 44.3 to 47.1%. Alone application of Caramba which induced minimal seed yield, but that treatment was responsible to increase oil content to its maximum level (47.1%) which was significantly higher than that of Moddus + Cantus Gold (44.3%), Caramba + Ortiva (44.8%) and Ortiva (45.3%), while it was statistically at par with that of all other fungicide treatments. Fungicidal treatment Moddus + Cantus Gold exhibited lowest oil content (44.3%) that was statistically same with that already mentioned treatments (Toprex + Ortiva and Ortiva) in this paragraph, and was significantly lower than that of all other fungicide treatments. As in the case of seed yield application of Ortiva in combination with other triazole fungicides (Toprex and Folicur) improved oil content (3%) over its combined application with Caramba. Alone application of Moddus significantly increased oil content (4%) compared with that of its combined application with Cantus Gold.

Saturated fatty acids

Palmitic acid was significantly affected by application of fungicides, while non significant differences were recorded for stearic acid among the treatments during this study (Table 20). Fungicidal treatment Folicur + Ortiva exhibited maximum value of palmitic acid (4.71%) which was statistically same with that of control (4.57%), while it was higher than that of all other fungicide treatments. Minimum value of palmitic acid (4.39%) was recorded in case of Harvesan (4.39%) which was significantly lower over Folicur + Ortiva and Control while statistically at par with other treatments.

Table 20: Effect of fungicides and growth regulator on concentration of fatty acid in the oil of rapeseed at Giessen 2008-09

Treatments	C16:0[1)]	C18:0	C18:1	C18:2	C18:3	C20:1
Control	4.57ab	1.63	59.8	18.9	10.6	1.41
Folicur	4.40 cd	1.66	60.7	19.2	10.3	1.56
Caramba	4.45 bcd	1.69	60.5	19.3	10.5	1.41
Cantus	4.40 cd	1.73	59.6	19.5	10.1	1.64
Prosaro	4.48 bcd	1.62	59.9	19.4	10.3	1.46
Proline	4.42 bcd	1.65	60.3	19.3	10.2	1.42
Harvesan	4.39 d	1.60	59.9	19.3	10.1	1.43
Moddus + Cantus Gold	4.42 bcd	1.62	60.0	19.4	10.3	1.44
Moddus	4.50 bcd	1.63	59.4	19.6	9.9	1.42
Ortiva	4.54 bcd	1.64	60.3	19.6	10.3	1.46
Toprex	4.48 bd	1.66	60.6	19.4	10.0	1.40
Toprex + Ortiva	4.54 bcd	1.57	59.1	19.3	10.1	1.40
Folicur + Ortiva	4.71 a	1.64	59.3	19.7	10.3	1.44
Caramba +Ortiva	4.55 bcd	1.65	59.5	19.7	10.4	1.44
$LSD_{0.05}$	**0.15**	**ns**	**ns**	**ns**	**ns**	**ns**

[1)] C16:0 = Palmitic acid, C18:0 = Stearic acid, C18:1 = Oleic acid, C18:2 = Linoleic acid, C18:3 = Linolenic acid, C20:1 = Eicosenoic acid.

Unsaturated fatty acids

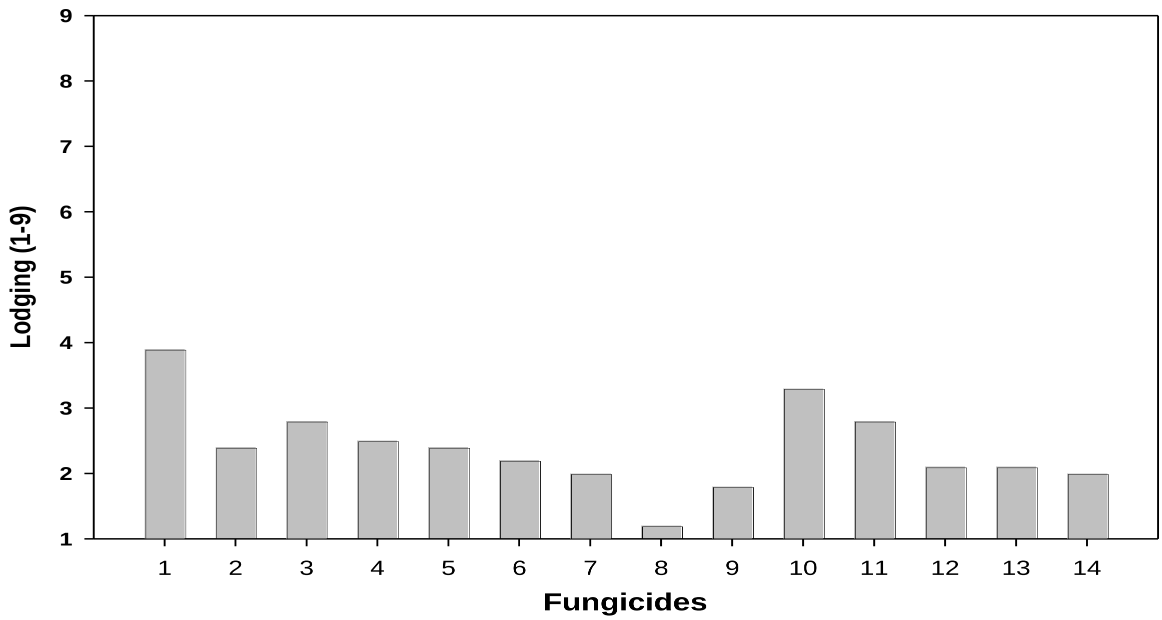
Concentration of all measured unsaturated fatty acids in the oil of rapeseed did not show significant differences among fungicide treatments (Table 20). Maximum oleic acid (60.7%) was recorded in case of application of Folicur, while Toprex + Ortiva gave minimum value of oleic acid (59.1%) over other treatments. Minimum concentration of linoleic acid was observed from Control (18.9 %), whereas combination of Ortiva with Folicur and Caramba increased it to its maximum level (19.7%) over other treatments. Alone application of Moddus gave least value of linolenic acid (9.9%), while most value (10.5%) was obtained in case of Caramba by other treatments.

4.4 Fungicide Experiment at Rauischholzhausen 2008-09

4.4.1 Field parameters

Lodging

Rate of lodging ranged from 1.2 to 3.9 during this study (Fig. 30). Maximum lodging (3.9) was observed from untreated plots and was followed by alone application of Ortiva (3.3) and these were higher than that of other treatments. Application of growth regulator Moddus alone as well as in combination with strobilurin fungicide (Cantus Gold) produced healthy plants which resist to lodging and giving lowest values of lodging 1.8 and 1.2 respectively by other fungicide treatments. More lodging (2.8) was recorded from Caramba alone treated plots than that of its application in combination with Ortiva. Ortiva alone applied plots were lodged more severely compared with its inclusion in triazole fungicides (Toprex, Folicur and Caramba). Harvesan performed better against lodging among all single applied fungicides.

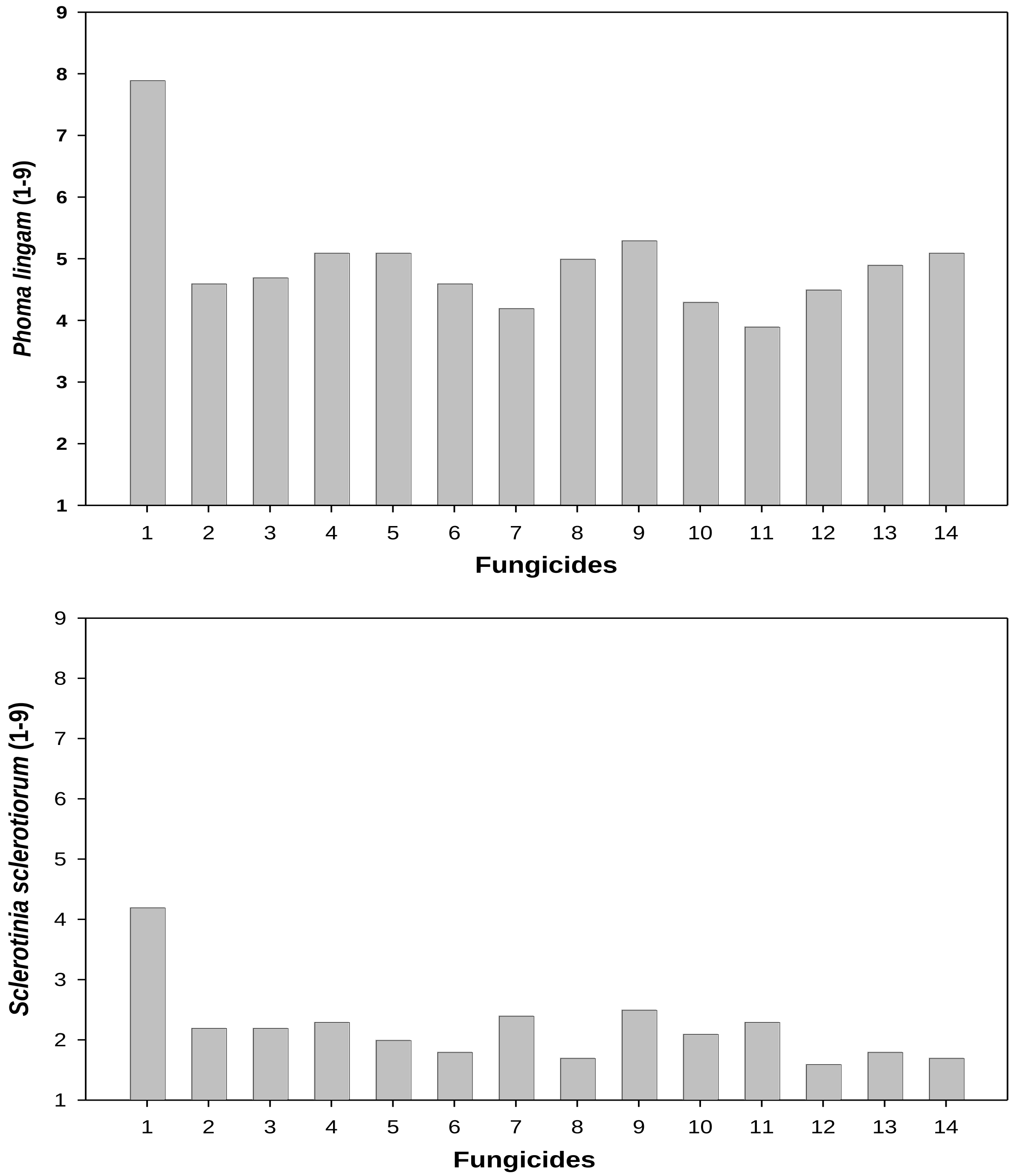


1. Control , **2.** Folicur, **3.** Caramba, **4.** Cantus, **5.** Prosaro, **6.** Proline, **7.** Harvesan, **8.** Moddus + Cantus Gold, **9.** Moddus, **10.** Ortiva, **11.** Toprex, **12.** Toprex + Ortiva, **13.** Folicur + Ortiva, **14.** Caramba + Ortiva

Figure 29: Effect of different fungicides on lodging of winter rapeseed at RH 2008-09

Diseases

Fig. 29 depicts the effect of fungicides on diseases (*Phoma lingam, Sclerotinia sclertiorum*) and lodging during this experiment in RH.



1. Control , **2.** Folicur, **3.** Caramba, **4.** Cantus, **5.** Prosaro, **6.** Proline, **7.** Harvesan, **8.** Moddus + Cantus Gold, **9.** Moddus, **10.** Ortiva, **11.** Toprex, **12.** Toprex + Ortiva, **13.** Folicur + Ortiva, **14.** Caramba + Ortiva

Figure 30: Effect of different fungicides on *Phoma lingam* and *Sclerotinia sclerotiorum* of winter rapeseed at RH 2008-09

Intensity of diseases was more severe in RH compared with Giessen during 2009. In RH infection of Phoma was more compared with Sclerotinia. Application of Toprex gave best control of Phoma (3.9) in comparison with that of all other fungicide treatments. Maximum damage due to Phoma (7.9) was observed from Moddus (5.3) and untreated plots by other treatments. Untreated plots were severely attacked with Sclerotinia (4.2) and was followed by alone application of Moddus (2.5) than that of all other treatments. Best control of Sclerotinia (1.6) was recorded from Toprex + Ortiva treated plots. Double application of fungicides reduced the incidence of Sclerotinia prominently compared with single application and control. In double applied plots scale of Sclerotinia was ranged from 1.6 to 1.8, while it varied from 1.8 to 3.9 in singly treated and control plots. Application of Proline reduced the incidence of Sclerotinia its minimum level (1.8) than that of all other single fungicide treatments and control.

Plant height

Application of fungicides significantly influenced the plant height at BBCH 80 in RH 2009 (Table 21). Short statured plants were produced after application of Caramba alone as well as its combined application with Ortiva compared with other treatments. Alone application of Caramba and Moddus and combined application of Caramba with Ortiva gave smallest values of PH 143.4, 144.4 and 144.1 cm respectively which were statistically at par among each other and with that of Folicur (144.6 cm), Cantus (147.4 cm) and control (147.6 cm) and were significantly lower than that of all other fungicidal treatments. Alone application of Moddus significantly decreased height of planting stand compared with its combined application with Cantus Gold. PH resulted maximal (151.6 cm) by alone application of Prosaro which was significantly higher than that of Folicur (144.6 cm), Caramba + Ortiva (144.1 cm), Moddus (144.4 cm) and Caramba (143.4 cm), while it was statistically similar by other fungicidal treatments including control.

TGW

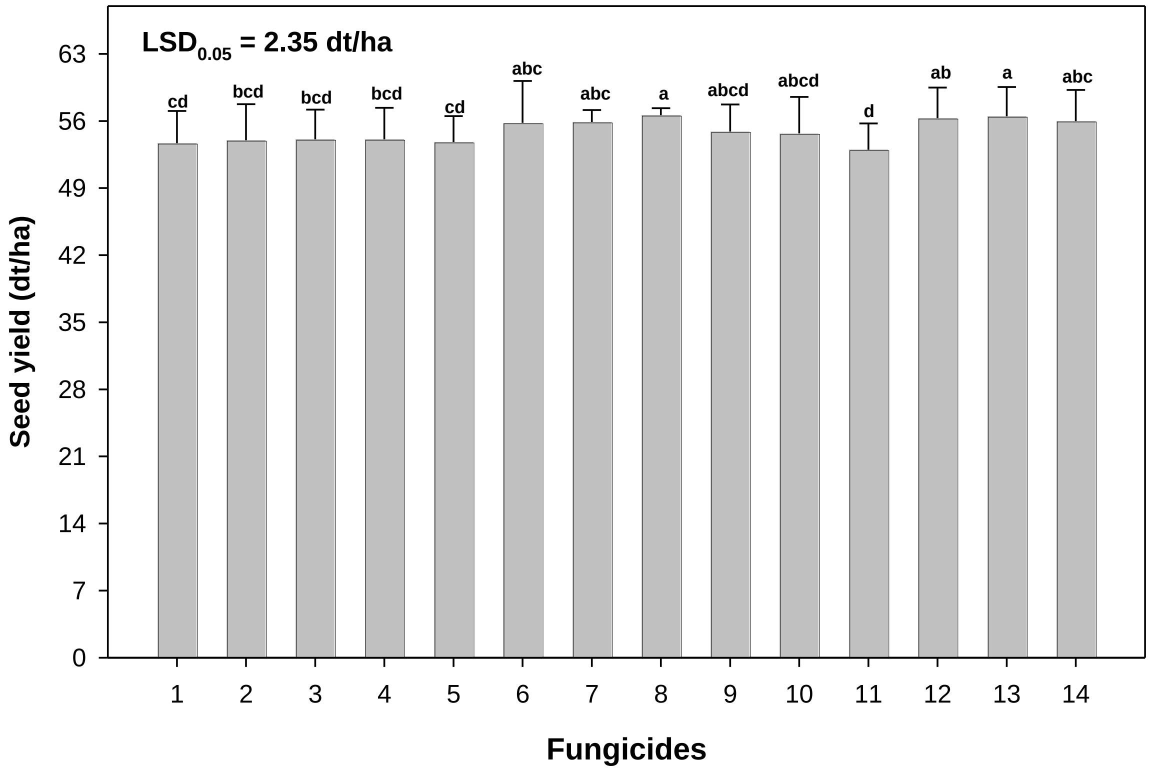
Non significant variations were observed by application of fungicides regarding TGW of winter rapeseed during this experiment (table 25). Maximum TGW (5.07 g) was recorded from the seed samples of those plots which were treated with Moddus alone and was followed by Proline (5.01 g), Harvesan (5.00 g), Toprex + Ortiva (4.98 g) and Toprex (4.96 g) and all these higher by all other treatments. Alone application of Folicur reduced TGW its minimal level (4.89 g) which was lowest than that of all other fungicidal treatments including control.

Table 21: Effect of fungicides and growth regulator on plant height (PH) and TGW of rapeseed at RH 2008-09

Treatments	Plant height (cm)	TGW (g)
Control	147.6 abc	4.93
Folicur	144.6 bc	4.89
Caramba	143.4 c	4.92
Cantus	147.4 abc	5.00
Prosaro	151.6 a	4.93
Proline	150.9 a	5.01
Harvesan	150.1 a	5.00
Moddus + Cantus Gold	150.8 a	4.91
Moddus	144.4 c	5.07
Ortiva	149.8 ab	4.90
Toprex	149.6 ab	4.96
Toprex + Ortiva	149.8 ab	4.98
Folicur + Ortiva	148.8 ab	4.95
Caramba + Ortiva	144.1 c	4.92
$LSD_{0.05}$	**5.35**	**ns**

Seed yield

Seed yield was influenced significantly by application of fungicides during this study in RH 2009 (Fig. 31). Seed yield ranged from 53.0 to 56.6 dt/ha among the treatments. Maximum seed yield (56.6 dt/ha) was obtained by application of Moddus + Cantus Gold which was statistically same and followed by Folicur + Ortiva (56.5 dt/ha), Toprex + Ortiva (56.3 dt/ha), Caramba + Ortiva (56.0), Harvesan (55.9 dt/ha), Proline (55.8 dt/ha), Moddus (54.9 dt/ha) and Ortiva (54.7 dt/ha) while it was significantly higher than that of all other fungicidal treatments including Control. Alone application of Toprex led to minimal seed yield (53.0 dt/ha) which was statistically at par with that of Control (53.7 dt/ha), Prosaro (53.8 dt/ha), Folicur (54.0 dt/ha), Caramba (54.1 dt/ha), Cantus (54.1 dt/ha), Moddus (54.7 dt/ha) and Moddus + Cantus Gold (54.9 dt/ha), while it was significantly lower than that of all other fungicidal treatments. Moddus + Cantus Gold application increased (3%) seed yield compared with that of alone application of Moddus. Significant reduction (6%) in seed yield was observed by alone application of Toprex compared with its inclusion in Ortiva. Small improvement in seed yield was observed in combined applications of Ortiva with triazole fungicides (Toprex, Folicur and Caramba) compared with alone application of Ortiva but seed yield had no significant variations among all these treatments. Combined application of Folicur with Ortiva significantly increased (4%) seed yield over alone application of Folicur. Among all those treatments where fungicides were applied singly, Harvesan gave maximum seed yield (55.9 dt/ha) which was significantly higher than that of Toprex (53.0 dt/ha), while it was statistically similar with that of all other fungicidal treatments including control.



1. Control , **2.** Folicur, **3.** Caramba, **4.** Cantus, **5.** Prosaro, **6.** Proline, **7.** Harvesan, **8.** Moddus + Cantus Gold, **9.** Moddus, **10.** Ortiva, **11.** Toprex, **12.** Toprex + Ortiva, **13.** Folicur + Ortiva, **14.** Caramba + Ortiva

Figure 31: Effect of different fungicides on seed yield of winter rapeseed ± SD at RH 2008-09

4.4.2 Quality parameters

Oil content

Oil content of rapeseed was significantly affected by application of fungicides during this study (Table 22). Oil accumulation ranged from 46.8 to 48.3%. Fungicidal treatment Caramba + Ortiva exhibited minimal oil content (46.8%) which was significantly lower than that of all other fungicidal treatments. Maximum oil content (48.3%) was recorded in case of Moddus + Cantus Gold and Toprex alone application which was statistically higher than that of Caramba + Ortiva (46.8%), while these were statistically same with all other treatments including control.

Protein content

Application of fungicides did not alter the protein content significantly in the seeds of winter rapeseed during this experiment. Maximum value of protein content (19.2%)

was recorded in the seeds of those plants which were treated with Moddus alone compared with all other treatments (Table 22). This maximum value of protein content was followed with the next value of 19.1% that obtained from those plots which were treated with Harvesan, Ortiva, Toprex and Ortiva + Toprex. Minimum protein content (18.5%) was obtained from Folicur, Caramba and Folicur + Ortiva by all other treatments including untreated control (18.8%).

Free fatty acids (FFA)

Fungicides changed the concentration of FFA significantly in the oil of rapeseed during this experiment (Table 22). Toprex + Ortiva application increased the concentration of FFA to its maximum level (1.01%) which was statistically at par and followed by Folicur + Ortiva (0.96%), Harvesan (0.95 %) and Moddus (0.89%), while it was significantly higher compared with all other treatments. Application of Prosaro improved the quality of rapeseed oil by reducing the concentration of FFA to its minimal level (0.59%) which was statistically same with that of Caramba (0.69%), Cantus (0.69%), control (0.71%) and Proline (0.74%), and was significantly lower than that of all other treatments. Alone applications of Toprex and Folicur significantly reduced FFA over its combined application with Ortiva.

Table 22: Effect of fungicides and growth regulator on quality parameters (oil content, protein content, FFA and PV) of rapeseed at Rauischholzhausen 2008-09

Treatments	Oil (%)	Protein (%)	FFA (%)	PV (meq/kg)
Control	47.8 a	18.8	0.71 de	7.16 cd
Folicur	47.6 a	18.5	0.75 cd	6.62 de
Caramba	47.8 a	18.5	0.69 de	5.03 e
Cantus	48.1 a	18.6	0.69 de	5.79 e
Prosaro	48.2 a	19.0	0.59 e	9.09 abcd
Proline	47.8 a	18.9	0.74 cde	6.10 e
Harvesan	47.8 a	19.1	0.95 ab	6.79 de
Moddus + Cantus Gold	48.3 a	18.7	0.77 cd	9.70 abc
Moddus	48.1 a	19.2	0.89 abc	5.20 e
Ortiva	48.1 a	19.1	0.85 bcd	7.30 bcde
Toprex	48.3 a	19.1	0.71 de	9.83 ab
Toprex + Ortiva	47.7 a	19.1	1.01 a	6.34 e
Folicur + Ortiva	47.7 a	18.5	0.96 ab	4.92 e
Caramba + Ortiva	46.8 b	18.7	0.83 bcd	10.38 a
$LSD_{0.05}$	**0.75**	**ns**	**0.160**	**2.55**

Peroxides value

Peroxides value (PV) in the oil of rapeseed was significantly influenced by application of fungicides (Table 22). Application of Caramba + Ortiva deteriorated the quality of rapeseed oil by increasing PV its maximum level (10.38 meq/kg), that was statistically at par and followed by Toprex (9.83 meq/kg), Moddus + Cantus Gold (9.70 meq/kg) and Prosaro (9.09 meq/kg), while it was significantly higher than that of all other fungicidal treatments. 4.92 meq/kg was the lowest PV recorded in the oil samples of Folicur + Ortiva treated plots, which was significantly lower than that of already mentioned treatments in this paragraph including control, while it was statistically similar with that of all other treatments. Alone applications of Folicur and Caramba significantly reduced PV over their combined application with Ortiva, while alone application of Toprex improved PV significantly than that of its combined application with Ortiva. Significant increase in PV of rapeseed oil was observed in case of application of Moddus + Cantus Gold in comparison to alone application of Moddus.

Saturated fatty acids

Significant differences were recorded in the concentration of saturated fatty acids (palmitic and stearic) by application of fungicides (Table 23). Moddus + Cantus Gold increased the concentration of palmitic acid its maximum level (4.63%) which was significantly lower than that of Cantus (4.38%), Folicur (4.39%), Folicur + Ortiva (4.42%), Caramba (4.42%) and untreated control (4.48%), while it was statistically at par with that of all other fungicidal treatments. Alone application of Caramba significantly reduced the concentration of palmitic acid in comparison with that of its combined application with Ortiva. In all cases of alone application of fungicides and growth regulator including control reduced palmitic acid slightly compared with double application of fungicides. Alone applications of Folicur and Cantus were responsible to reduce palmitic acid to its minimum level, which was statistically similar with that of Folicur + Ortiva, Caramba, control and Toprex, and that was significantly lower than that of all other treatments. Maximum concentration of stearic acid (1.80%) was measured in the oil samples of Caramba alone application which was significantly higher than that of Moddus (1.66%), control (1.71%), Ortiva (1.73%) and Toprex + Ortiva (1.75%), while it was statistically similar with that of all other treatments. Minimum concentration of stearic acid (1.66%) was recorded in case of Moddus application which was statistically at par with that of control, Ortiva and Toprex + Ortiva, while it was significantly lower than that of all other treatments.

Unsaturated fatty acids

Concentration of oleic acid in the oil of rapeseed was not affected significantly by application of fungicides (Table 23). Concentration of oleic acid was ranged from

59.7 to 60.9% during this experiment. 59.7% was the lowest concentration which was recorded in the oil samples of control and alone Moddus treated plots, while maximum oleic acid (60.9%) was measured by Harvesan and Toprex alone applications which were followed by Caramba + Ortiva (60.8%), Prosaro (60.7%), Cantus (60.5%) and Proline (60.5%) and these all were higher than that of all other treatments. Concentration of oleic acid was increased (0.2 to 0.8%) by Combined application of Ortiva with triazole fungicides (Toprex, Folicur and Caramba) compared with alone application of Ortiva.

Linoleic acid was significantly influenced by application of fungicides (Table 23). Alone application of Moddus increased the concentration of linoleic acid to its maximum level (20.0%) which was significantly higher than that of all other fungicide treatments. Lowest concentration of linoleic acid (18.9%) was measured from Caramba, Cantus and Prosaro treatments which were statistically similar with that of Proline, Harvesan and Folicur + Ortiva (19.0%), while it was significantly lower than that of all other fungicidal treatments including control. Significant reduction in the concentration of linoleic was recorded with Caramba alone application in comparison with Caramba + Ortiva.

Table 23: Effect of fungicides and growth regulator on the concentration of fatty acid in the oil of rapeseed at RH 2008-09

Treatments	C16:0[1)]	C18:0	C18:1	C18:2	C18:3	C20:1
Control	4.48 bc	1.71 cd	59.7	19.3 b	10.1 ab	1.35
Folicur	4.39 c	1.76 abc	60.1	19.2 bc	10.1 ab	1.39
Caramba	4.43 bc	1.80 a	60.4	18.9 d	9.8 c	1.37
Cantus	4.38 c	1.79 ab	60.5	18.9 d	9.8 c	1.46
Prosaro	4.57 ab	1.77 ab	60.7	18.9 d	9.9 bc	1.40
Proline	4.57 ab	1.78 ab	60.5	19.0 cd	9.9 bc	1.36
Harvesan	4.57 ab	1.76 abc	60.9	19.0 cd	9.8 c	1.38
Moddus + Cantus Gold	4.63 a	1.76 abc	60.3	19.4 b	9.9 bc	1.37
Moddus	4.58 ab	1.66 d	59.7	20.0 a	10.4 a	1.35
Ortiva	4.56 ab	1.73 bcd	60.0	19.2 bc	10.2 ab	1.36
Toprex	4.51 abc	1.77 ab	60.9	19.2 bc	10.0 bc	1.36
Toprex + Ortiva	4.58 ab	1.75 bcd	60.4	19.2 bc	10.0 bc	1.41
Folicur + Ortiva	4.42 bc	1.77 ab	60.2	19.0 cd	10.0 bc	1.44
Caramba +Ortiva	4.61 a	1.77 ab	60.8	19.3 b	9.9 bc	1.34
$LSD_{0.05}$	**0.15**	**0.04**	**ns**	**0.25**	**0.26**	**ns**

[1)] C16:0 = Palmitic acid, C18:0 = Stearic acid, C18:1 = Oleic acid, C18:2 = Linoleic acid, C18:3 = Linolenic acid, C20:1 = Eicosenoic acid.

Linolenic acid was significantly differed among the treatments during this experiment (Table 23). Like in the case of linoleic acid, here also alone application of Moddus gave maximum value of linolenic acid (10.4%) which was statistically similar and followed by Ortiva (10.2%), Folicur (10.1%) and Control (10.1%), but it was significantly higher than that of all other treatments. Minimum value of linolenic acid (9.8%) was recorded by alone application of Caramba, Cantus and Harvesan which was significantly lower than that of already mentioned treatments which produced more linolenic, while it was statistically at par with that of all other treatments. Concentration of eicosenoic acid was not altered significantly by application of fungicides. Value of eicsenoic acid was ranged from 1.34 to 1.46%. Maximum concentration of eicosenoic acid (1.46%) was measured in case of alone application of Cantus, while minimum value (1.34%) from Carambra + Ortiva by other treatments.

4.5 Fungicide × Sulphur Experiment at RH 2009-10

4.5.1 Field parameters

Leaf area index (LAI)

During this experiment LAI was measured at three different growth stages of winter rapeseed (Table 24). LAI was significantly affected at BBCH 60 which was one week before second application of fungicides. At this stage application of Folicur reduced LAI to its minimal level (5.20), which was statistically similar with that of control (5.40), Moddus (5.45) and Folicur + Ortiva (5.51), and it was significantly lower than that of all other treatments. Application of Toprex gave maximum LAI at BBCH 60 which was significantly higher than that of all other fungicides with the exception of Caramba which were applied during 1st application. At this stage sulphur application did not change LAI significantly. No interaction between fungicides and sulphur was observed regarding LAI at BBCH 60.

LAI was varied significantly among fungicidal treatments after one week of 2nd application at BBCH 70 (table 28). Lowest LAI was recorded from untreated plots, which was statistically at par with that of Folicur (5.59), Moddus (5.73), Caramba (5.76), Toprex (5.76) and Prosaro (5.78), while it was significantly lower than that of all other fungicidal treatments at BBCH 70. Maximum LAI (6.16) was noted by application of Toprex + Ortiva which was statistically at par with that of all double applied treatments as well as single applied Harvesan, Proline and Cantus, while it was significantly higher than that of all other fungicidal treatments. Among fungicidal treatments with the exception of control, alone application of Folicur reduced LAI maximal at BBCH 70. Sulphur application did not change LAI significantly at BBCH 70. Non significant interaction of fungicides x sulphur was observed regarding LAI at BBCH 70.

LAI was affected significantly at BBCH 78 by application of fungicides and sulphur (table 28). Caramba + Ortiva led to maximum LAI (4.74) at BBCH 78, which was statistically similar with that of all double applied treatment and also same with single applied Caramba, Cantus and Toprex, while this value was significantly higher than that of all other treatments at BBCH 78. Alone application of Ortiva significantly reduced LAI compared with its inclusion in Caramba, while it was significantly similar compared with its other combinations. At BBCH 78 minimum LAI (3.94) was noted from untreated plots which was significantly lower than that of all double applied treatments and single applied Cantus, while it was statistically at par with all other fungicidal treatments. LAI of Cantus was maximal among all alone applied and control treatments at BBCH 78. Significant interaction between fungicides and sulphur was observed for LAI at BBCH 78.

Table 24: Effect of fungicides and growth regulator on leaf area index and plant height (PH) at different growth stages of rapeseed under two levels of sulphur at RH 2009-10

Treatment	**LAI**			**Plant height (cm)**	
	BBCH 60	BBCH 70	BBCH 78	BBCH 62	BBCH 70
Control	5.40 cd	5.51 e	3.94 e	139.4 abcd	141.6 abc
Folicur	5.20 d	5.59 de	4.08 de	134.4 f	135.9 d
Caramba	5.61 abc	5.76 cde	4.34 abcde	136.6 cdef	140.3 abcd
Cantus	5.63 abc	6.04 abc	4.44 abcd	142.2 a	144.1 a
Prosaro	5.49 bcd	5.78 cde	4.13 cde	137.8 bcdef	140.6 abcd
Proline	5.58 abc	5.90 abcd	4.01 de	139.1 abcde	143.1 ab
Harvesan	5.58 abc	5.91 abc	4.24 bcde	139.7 abc	141.9 abc
Mod + Cantus Gold	5.60 abc	5.94 abc	4.54 abc	138.1 bcdef	139.4 abcd
Moddus	5.45 bcd	5.73 cde	4.18 bcde	135.3 def	138.1 bcd
Ortiva	5.67 abc	5.84 bcd	4.20 bcde	141.6 ab	143.1 ab
Toprex	5.63 abc	5.76 cde	4.59 ab	140.6 abc	143.1 ab
Toprex + Ortiva	5.83 a	6.16 a	4.55 abc	141.3 ab	142.8 ab
Folicur + Ortiva	5.51 bcd	5.96 abc	4.54 abc	135.0 ef	137.5 cd
Caramba + Ortiva	5.75 ab	6.14 ab	4.74 a	138.8 abcde	140.3 abcd
Fun. ($LSD_{0.05}$)	**0.31**	**0.31**	**0.44**	**4.20**	**4.97**
S_1	5.54	5.85	4.28 b	139.8 a	141.7
S_2	5.59	5.87	4.36 a	137.3 b	140.0
Sul. ($LSD_{0.05}$)	**ns**	**ns**	**0.17**	**1.60**	**ns**
Fun. x Sul. ($LSD_{0.05}$)	**ns**	**ns**	**0.62**	**ns**	**ns**

Mod '= Moddus, S_1 = 0 kg Sulphur/ha, S_2 = 72kg Sulphur/ha

Plant height

Plant height (PH) was measured at two growth stages (BBCH 62 and 70) of winter rapeseed during this study which showed significant variations by application of fungicides (Table 24). Short statured plants were obtained from those plots where

Folicur was applied during 1st application at BBCH 53 over all other treatments. Value of PH (134.4 cm) from Folicur alone treated plants was statically similar with that of Folicur + Ortiva (135.0 cm), Moddus alone (135.3 cm), Caramba alone (136.6 cm), Prosaro alone (137.8) and Moddus + Cantus Gold (138.1 cm), while it was significantly lower compared with all other fungicidal treatments including control at BBCH 62. Exactly same results regarding PH of rapeseed to the fungicdes were recorded at BBCH 70. Alone application of cantus improved PH to its maximal level among the treatments at both growth stages. PH of Cantus treated plants was significantly higher than that of Folicur included treatments and Moddus alone at both growth stages of measurement, while Caramba alone, Prosaro alone and Moddus + Cantus Gold attained significantly lower PH at BBCH 62, and it was statistically at par with that of all other fungicidal treatments including control. Application of Moddus in combination with Cantus Gold slightly improved PH compared with Moddus alone. Combinations of Ortiva with Toprex and Folicur markedly improved PH compared with the inclusion of Ortiva in Folicur. Application of sulphur reduced PH significantly at BBCH 62, while PH was not altered significantly by application of sulphur at BBCH 70. There was no interaction between fungicides and sulphur regarding PH at both growth stages of measurement.

Seed yield components

Data regarding seed yield components (Table 25) during this experiment was not statistically analyzed because data was collected only from one replication by collecting 20 plants from each plot. These parameters were compared by mean values among the treatments.

Maximum number of pods per plant (221.8) was recorded in case of Moddus and was followed by Ortiva alone or in combination with Folicur (200.8), Moddus + Cantus Gold (195.4) and Folicur (188.4) and all these were higher by other fungicidal treatments. Alone application of Caramba and Toprex as well as control treatment gave minimum number of pods per plant 138.0, 147.2 and 150.4 respectively. Inclusion of Ortiva to the triazole fungicides (Toprex, Caramba and Folicur) enhanced pods per plant compared with alien application of these triazole fungicides. Pods per plant were increased by Moddus alone compared with Moddus + Cantus Gold. Performance of Caramba alone as well as in combination with Ortiva was not optimal regarding number of pods per plant compared with other treatments. Application of sulphur slightly increased the number of pods per plant compared with no application of sulphur.

Application of Harvesan gave maximum pod length (7.15 cm) as well as maximum number of seeds per pod over other treatments. Maximum value of pod length was followed by Caramba alone (6.77 cm) and Folicur + Ortiva (6.64 cm). Minimum pod length (6.01 cm) was recorded from those plants which were attained maximum number of pods in case of Moddus alone application than that of all other treatments. Fungicidal treatments Proline and control reduced seeds per pod its minimal level (17.4) compared with all other treatments. Alone applications of Ortiva and Toprex performed better to increase number of seeds per pod compared with their combined application. Single applied treatments with the exception of Cantus and Proline gave more seeds per pod than that of double applied fungicides.

Table 25: Effect of fungicides and growth regulator on pods/plant (P/Pl), pod length (PL), seeds/pod (S/Pd), main-branches (MB), sub-branches (SB) and height of main stem from soil surface to 1st internode (PH_1) of rapeseed under two levels of sulphur at RH 2009-10

Treatment	P/Pl	PL (cm)	S/Pd	MB	SB	PH_1 (cm)
Control	150.4	6.30	17.3	5.9	4.8	30.3
Folicur	188.4	6.58	19.7	6.9	5.4	32.7
Caramba	138.0	6.77	19.4	5.5	4.6	34.6
Cantus	168.9	6.28	17.7	6.4	4.5	32.8
Prosaro	174.9	6.51	20.3	5.7	6.4	32.2
Proline	176.4	6.30	17.4	6.8	4.6	35.7
Harvesan	173.6	7.15	21.9	6.8	5.3	30.8
Moddus + Cantus Gold	195.4	6.27	19.7	6.9	6.3	29.4
Moddus	221.8	6.01	21.1	7.6	8.2	27.3
Ortiva	200.8	6.61	20.2	7.0	5.5	29.2
Toprex	147.2	6.06	18.4	5.7	2.5	31.1
Toprex + Ortiva	179.4	6.23	17.8	6.5	4.8	33.3
Folicur + Ortiva	200.8	6.64	19.0	7.3	5.1	30.3
Caramba + Ortiva	154.6	6.24	17.5	6.0	4.6	37.9
S_1	172.2	6.43	19.0	6.8	5.0	31.1
S_2	180.7	6.42	19.2	6.2	5.4	32.8

S_1 = 0 kg Sulphur/ha, S_2 = 72kg Sulphur/ha

Maximum number of main (7.6) and sub (8.2) branches were recorded in case of Moddus alone application by other treatments. Alone application of Toprex reduced number of sub branches its minimum level (2.5) compared with other treatments. Minimum number of main branches per plant (5.5) was counted in case of alone application of Caramba in comparison with other treatments. Number of main and sub-branches were recorded 5.9 and 4.8 respectively from untreated plants. Among double applied treatments Folicur + Ortiva performed better to enhance main-braches per plant (7.3), while Moddus + Cantus Gold gave maximum number of sub brances (6.3). Performance of Caramba alone in single applied treatments as well as its combined application with Ortiva was not optimal to improve number of main and sub branches among double applied treatments. Height of main stem from soil surface to 1st internode (PH_1) was recorded maximal in case of Caramba + Ortiva, whilst PH_1 was lowest by alone application of Moddus compared with other all treatments. Alone application of Moddus at BBCH 65 was considered best to improve morphological parameters of winter rapeseed compared with other fungicidal treatments including control during this experiment. There was not a pronounced effect of sulphur application to improve seed yield components.

Diseases

Maximum severity of Phoma (5.1) was recorded from untreated plots which was followed by Moddus alone (4.5) and these were higher than that of all other treatments (Table 26). Combination of Ortiva with triazole fungicides (Toprex, Folicur and Caramba) gave best control against Phoma compared with other treatments during this experiment. Among single applied treatments Ortiva reduced the incidence of Phoma its minimal level (2.8), while highest levels of phoma 4.5, 3.9 and 3.8 were recorded from Moddus, Harvesan and Caramba treated plots respectively. Here also like in case of Phoma, maximum symptoms of Sclerotinia 5.5 and 4.6 were recorded from control and Moddus alone applied plots respectively in comparison with other treatments. Toprex + Ortiva treated plants exhibited minimal level of Sclerotina (1.9) compared than that of all other treatments. Alone application of Folicur at BBCH 53 increased the level of Sclerotinia compared with other single applied treatments but it was less than Moddus. Minimum incidence of Sclerotinia (2.8) was observed in case of application of Harvesan among single applied treatments. Prosaro which was the mixture of Caramba and Folicur reduced the incidence of Sclerotina compared with their alone applications. Among double applied treatments Moddus + Cantus Gold had maximum levels for both diseases. Inclusion of Ortiva to the Toprex was considered best to reduce the incidence of both diseases its minimal level during this experiment. For both diseases double applied fungicides gave better control over single applied treatments.

Lodging

Rate of lodging was ranged from 1.7 to 3.4 during this study (Table 26). Inclusion of growth regulator Moddus to the Cantus Gold led to minimal lodging (1.4) compared with other treatments. As severity of diseases had direct influence on rate of lodging, hence fungicidal treatment Toprex + Ortiva which was best against diseases also reduced lodging. Maximum lodging (3.4) was recorded from untreated plots which was followed by Toprex alone (2.9) by other treatments. Among single applied treatments Harvesan was the best against lodging. Application of sulphur did not have any prominent effect against diseases and lodging.

TGW

Application of fungicides did not influence TGW significantly (Table 26). Value of TGW varied among 4.20 to 4.55 g during this study. Maximum TGW (4.55 g) was recorded in case of application of Moddus in combination with Cantus Gold which was followed by Harvesan (4.53 g) and Proline (4.50 g) and these were higher than that of all other treatments. Minimum values of TGW 4.20 and 4.33 g were measured from Caramba + Ortiva and contol plots respectively over other treatments. Among single applied treatments Caramba and Cantus gave lower values of TGW which were near to control. TGW was not affected significantly by application of sulphur. There was no interaction between fungicides and sulphur regarding TGW.

Table 26: Effect of fungicides and growth regulator on *Phoma lingam*, *Sclerotinia sclerotiorum*, lodging, TGW and seed yield of rapeseed under two levels of sulphur at RH 2009-10

Treatment	Phoma (1-9)	Sclero (1-9)	Lodging (1-9)	TGW (g)	Seed yield (dt/ha)
Control	5.1	5.5	3.4	4.33	33.2
Folicur	3.6	4.0	2.2	4.48	33.3
Caramba	3.8	3.8	2.2	4.34	33.5
Cantus	3.6	3.1	2.0	4.37	36.9
Prosaro	3.6	3.1	2.4	4.48	36.5
Proline	3.1	3.0	2.3	4.50	35.3
Harvesan	3.9	2.8	1.8	4.53	36.7
Moddus + Cantus Gold	3.0	3.1	1.4	4.55	35.6
Moddus	4.5	4.6	2.0	4.44	34.6
Ortiva	2.8	3.0	2.4	4.37	36.1
Toprex	3.0	2.9	2.9	4.47	35.7
Toprex + Ortiva	1.6	1.9	1.7	4.43	37.0
Folicur + Ortiva	1.8	2.3	2.4	4.47	34.9
Caramba + Ortiva	1.8	2.4	2.8	4.20	35.6
Fun. ($LSD_{0.05}$)	**-**	**-**	**-**	**ns**	**ns**
S_1	3.4	3.4	2.3	4.47	34.9
S_2	3.0	3.2	2.2	4.38	35.8
Sul. ($LSD_{0.05}$)	**-**	**-**	**-**	**ns**	**ns**
Fun. x Sul. ($LSD_{0.05}$)	**-**	**-**	**-**	**ns**	**ns**

S_1 = 0 kg Sulphur/ha, S_2 = 72kg Sulphur/ha

Seed yield

Seed yield of winter rapeseed did not alter significantly by application of fungicides during this experiment (Table 26). Untreated plots gave lowest seed yield (33.2 dt/ha) compared with other treatments. Application of Toprex + Ortiva which gave best control against diseases and lodging also enhanced seed yield its maximal level (37.0 dt/ha), and was followed by alone applied Cantus (36.9 dt/ha), Harvesan (36.7 dt/ha) and Prosaro (36.5 dt/ha) which were higher than that of all other treatments. Application of Folicur at BBCH 53 alone as well as in combination with Ortiva was not considered optimal to improve seed yield compared with other treatments. Among alone applied treatments Folicur and Caramba gave lowest values of seed yield 33.3 and 33.5 dt/ha respectively over other treatments. Combination of Folicur and Proline in the form of Prosaro markedly improved seed yield compared with their alone application. Application of Cantus which produced tallest plants and Harvesan which had better control against lodging and Sclerotinia gave maximum values of seed yield among single applied treatments. Combination of growth regulator Moddus with Cantus Gold increased seed yield (3%) compared with alone application of Moddus. Application of Ortiva in combination with Toprex was found to be best to improve seed yield compared with alone applications of Toprex and Ortiva as well as combined application of Ortiva with Folicur and Caramba. Application of sulphur improved seed yield (0.9 dt/ha) non significantly compared with unapplied. Non significant interaction between fungicides and sulphur was observed for seed yield.

4.5.2 Quality parameters

Oil content

Oil content was significantly influenced by the application of fungicides (Table 27). Maximum oil accumulation (46.3%) in the seeds of rapeseed was recorded in case of application of Toprex + Ortiva which was statistically at par and followed by Folicur and Prosaro (45.5%), while it was significantly higher than that of all other treatments. Alone application of Moddus gave lowest value of oil content (44.6%) which was significantly lower than that of Folicur, Prosrao, Ortiva alone and combinations of Ortiva with triazole fungicides (Toprex, Folicur and Caramba), whilst it was statistically similar with that of all other treatments including control. Among single applied treatments performance of Prosaro was best to increase seed yield as well as oil content. Harvesan enhanced seed yield, while it reduced oil content compared with untreated control. Combination of Moddus with Cantus Gold slightly improved oil accumulation compared with Moddus alone. Application of Toprex in combination with Ortiva significantly improved oil content over their alone applications. Sulphur application did not give any variation in the oil content of seeds. Interaction between fungicides and sulphur was found to be significant for oil content during this experiment.

Protein content

Protein content in the seeds of winter rapeseed was not affected significantly by the application of fungicides (Table 27). Seeds of untreated plants attained minimal protein content (19.6%) over other treatments. Maximum protein content (20.4%) was recorded in case of Caramba alone application. Lower protein content was noted in all cases of double applied treatment including control compared with single applied treatments with the exception of Toprex alone. Application of sulphur significantly improved protein content compared with unapplied sulphur treatment. There was no interaction between fungicides and sulphur for protein content.

Table 27: Effect of fungicides and growth regulator on quality parameters (oil content, protein content, FFA, PV and GSL) of rapeseed under two levels of sulphur at RH 2009-10

Treatment	Oil (%)	Protein (%)	FFA (%)	PV (meq/kg)	GSL (mmol/g)
Control	44.9 cd	19.6	0.46 e	3.17 g	13.5
Folicur	45.7 ab	20.1	0.49 de	3.62 cdef	14.2
Caramba	45.2 bcd	20.4	0.52 cde	4.53 a	12.8
Cantus	45.3 bcd	20.2	0.55 bcde	3.46 efg	13.3
Prosaro	45.7 ab	20.2	0.49 de	3.39 fg	12.8
Proline	45.1 bcd	20.0	0.54 bcde	4.00 bc	13.1
Harvesan	44.8 cd	20.0	0.59 abc	3.52 defg	13.7
Moddus + Cantus Gold	45.0 bcd	19.7	0.57 abcd	4.02 bc	12.6
Moddus	44.6 d	20.2	0.51 cde	3.92 bcd	11.9
Ortiva	45.5 bc	20.2	0.54 bcde	3.93 bcd	13.0
Toprex	45.2 bcd	19.9	0.53 bcde	3.96 bc	12.7
Toprex + Ortiva	46.3 a	19.9	0.65 a	4.16 ab	12.2
Folicur + Ortiva	45.5 bc	19.8	0.59 abc	3.32 fg	13.4
Caramba + Ortiva	45.4 bc	19.7	0.62 ab	3.85 bcde	12.8
Fun. ($LSD_{0.05}$)	**0.72**	**ns**	**0.10**	**0.41**	**ns**
S_1	45.3	19.2 b	0.57 a	2.68 b	12.4 b
S_2	45.3	20.8 a	0.52 b	4.87 a	13.6 a
Sul. ($LSD_{0.05}$)	**ns**	**0.27**	**0.04**	**0.16**	**0.52**
Fun. x Sul. ($LSD_{0.05}$)	**1.02**	**ns**	**ns**	**0.58**	**ns**

S_1 = 0 kg Sulphur/ha S_2 = 72kg Sulphur/ha

Free fatty acids

Application of fungicides changed the concentration of FFA rapeseed oil significantly (Table 27). Value of FFA ranged from 0.46 to 0.65% during this experiment. Toprex + Ortiva which gave maximum seed yield as well as oil content, were also responsible for maximum FFA level (0.65%), while oil samples of untreated plants attained lowest value of FFA (0.46%) in comparison with other treatments. Among single applied treatments, Harvesan induced maximum FFA (0.59%) which was significantly higher than that of control (0.46%), while Folicur (0.49%) and Prosaro (0.49%) were statistically similar with that of all other single applied treatments. All double applied treatments did not alter FFA significantly among each other. Slightly increasing trend in the concentration of FFA was observed in case of double applied treatments compared with single applied including control. Sulphur application significantly reduced FFA in rapeseed oil compared with no application of sulphur. Interaction between fungicides and sulphur was observed non significant for FFA.

Peroxide value

Fungicide application significantly changed the peroxides value (PV) in rapeseed oil (Table 27). Maximum PV (4.53 meq/kg) was recorded in case of alone application of Caramba which was statistically at par and followed by Toprex + Ortiva (4.16 meq/kg) and it was significantly higher than that of all other treatments including control. Lowest PV (3.17 meq/kg) was noted from untreated control samples which was significantly lower than that of double applied treatments with the exception of Folicur + Ortiva and single applied treatments with the exception of Cantus, Prosaro and Harvesan. Application of Prosaro reduced the PV to its lowest level (3.39 meq/kg) among single applied treatments which was significantly lower than than of Caramba, Toprex, Ortiva and Proline, while it was statistically similar with other single applied treatments including control. Application of sulphur significantly increased PV in the oil of rapeseed in comparison with no application of sulphur. Interaction between fungicides and sulphur was found to be significant regarding PV.

Glucosinolates

Glucosinolates (GSL) in the seeds of rapeseed was not influenced significantly by application of fungicides (Table 27). Alone application of Folicur at BBCH 53 induced maximum value of GSL (14.2 mmol/g) compared with other treatments. This treatment was followed by Harvesan (13.7 mmol/g), control (13.5 mmol/g) and Folicur + Ortiva (13.4 mmol/g). Minimum GSL (11.9 mmol/g) was recorded in case of alone application of Moddus. Alone application of Folicur among single applied treatments and combination of Folicur with Ortiva led to maximum GSL in double applied treatments. Application of sulphur markedly increased GSL in the seeds of rapeseed compared with unapplied treatment. There was no interaction between fungicides and sulphur regarding GSL.

Saturated fatty acids

Palmitic acid was significantly affected by the application of fungicides (Table 28). Untreated control exhibited maximum concentration of palmitic acid (4.84%) which was statistically similar and followed by Caramba (4.80%), Folicur (4.75%) and Cantus (4.75%), while all these were significantly higher than that of other treatments. Alone application of Ortiva and Toprex as well as Ortiva in combination with triazole fungicides reduced the concentration of palmitic acid compared with other treatments. Among single applied treatments Ortiva alone caused significantly lower concentration of palmitic acid over other treatments with the exception of Moddus alone.

Table 28: Effect of fungicides and growth regulator on the concentration of fatty acids in the oil of rapeseed under two levels of sulphur at RH 2009-10

Treatment	C16:0[1)]	C18:0	C18:1	C18:2	C18:3	C20:1
Control	4.84 a	1.75	60.2	19.6 b	9.73	1.24 e
Folicur	4.75 a	1.73	60.1	19.5 bc	9.77	1.28 cde
Caramba	4.80 a	1.75	60.2	19.5 bc	9.70	1.25 de
Cantus	4.75 a	1.74	60.2	19.3 cd	9.60	1.25 de
Prosaro	4.54 bc	1.74	60.6	19.4 bcd	9.71	1.31 abcde
Proline	4.56 b	1.76	60.5	19.3 cd	9.69	1.32 abcd
Harvesan	4.56 b	1.74	60.3	19.5 bc	9.76	1.33 abc
Moddus + Cantus Gold	4.51 bc	1.73	60.3	19.6 b	9.72	1.30 bcde
Moddus	4.46 bcd	1.72	59.9	19.9 a	9.80	1.37 ab
Ortiva	4.38 d	1.75	60.6	19.3 cd	9.64	1.34 abc
Toprex	4.43 cd	1.76	59.9	19.5 bc	9.54	1.38 a
Toprex + Ortiva	4.43 cd	1.75	60.5	19.4 bcd	9.61	1.33 abc
Folicur + Ortiva	4.34 d	1.73	60.7	19.2 d	9.79	1.33 abc
Caramba + Ortiva	4.38 d	1.73	60.4	19.5 bc	9.73	1.34 abc
Fun. ($LSD_{0.05}$)	**0.12**	**ns**	**ns**	**0.24**	**ns**	**0.07**
S_1	4.56	1.76 a	60.2 b	19.6 a	9.76 a	1.32
S_2	4.54	1.72 b	60.5 a	19.3 b	9.64 b	1.30
Sul. ($LSD_{0.05}$)	**ns**	**0.01**	**0.22**	**0.09**	**0.02**	**ns**
Fun. x Sul. ($LSD_{0.05}$)	**0.16**	**ns**	**ns**	**ns**	**ns**	**ns**

[1)] C16:0 = Palmitic acid, C18:0 = Stearic acid, C18:1 = Oleic acid, C18:2 = Linoleic acid, C18:3 = Linolenic acid, C20:1 = Eicosenoic acid.
[2)] S_1 = 0 kg Sulphur/ha, S_2 = 72kg Sulphur/ha

Unsaturated fatty acids

Oleic acid which is the major unsaturated fatty acid of rapeseed oil did not show significant differences by application of fungicides (Table 28). Sulphur application significantly increased oleic acid. No interaction was observed for oleic acid. Application of fungicides significantly altered the concentration of linoleic acid in the oil of rapeseed during this experiment (table 32). Maximum concentration of linoleic acid (19.9%) was found in oil samples of Moddus (alone treatment) which was significantly higher than that of all other treatments. Lowest concentration of linoleic acid (19.2%) was recorded in case of Folicur + Ortiva which was statistically at par with Toprex + Ortiva, while it was significantly lower than that all other double applied treatments including Control. Among single applied treatments minimum

concentration of linoleic acid (19.3%) was recorded from Cantus, Proline and Ortiva treatments which were significantly lower than that of Moddus (19.9%) and Control (19.6%), and were statistically at par with other single applied treatments. Sulphur application significantly reduced the concentration of linoleic acid over no application. There was no interaction between fungicides and sulphur for linoleic acid.
Non significant effects of sulphur application on the concentration of palmitic acid were observed. Interaction between fungicides and sulphur was recorded significant regarding palmitic acid.Very small change in the concentration of stearic acid was recorded among the treatments. Application of sulphur significantly decreased the concentration of palmitic acid in comparison with no application. There was no interaction between fungicides and sulphur for stearic acid.

Linolenic acid was not affected significantly by application of fungicides. Like in case of linoleic acid alone application of Moddus also gave maximum concentration of linolenic acid (9.80%) compared with other treatments. Sulphur application significantly decreased linlenic acid over no application. No interaction was observed. Concentration of eicosenoic acid was significantly affected by application of fungicides. Control treatment gave lowest concentration of eicosenoic acid (1.24%) which was significantly lower than all Ortiva, Toprex Moddus, Harvesan and Proline included treatments, while it was statistically at par with other treatments. Application of sulphur did not change the concentration of eicosenoic acid significantly. No interaction was observed among the treatments.

4.6 Fungicide × Nitrogen Experiments 2008-09

4.6.1 Field parameters

Leaf area index (LAI)

Upon application of fungicides LAI of rapeseed was influenced significantly except BBCH 76, 84 and 86 at Giessen in the executed experiment (Table 29). Significantly higher LAI (3.58) was recorded at BBCH 56 from autumn (1^{st}) applied Caramba compared with that of all other treatments including control. At BBCH 56 spring (2^{nd}) applied Caramba + 3^{rd} applied Cantus Gold (no 7) gave minimum LAI (2.84) which was statistically at par with fungicidal treatments (no 5, 6, 9, 10 and 12) and it was significantly lower than that of all other fungicidal treatments including control. Next measurement of LAI was carried out at BBCH 62 which showed significant differences among fungicidal treatments. At this stage autumn applied (no 2, 3 and 4) and Carax included treatments (no 12 and 13) gave maximum LAI by other treatments and these were statistically similar among each other. Folicur + Cantus Gold (no 9) reduced LAI to its minimal level (4.62) at BBCH 62, which was significantly lower than that of autumn applied and Carax included treatments, while it was statistically similar with that of all other treatments with the exception of control and Toprex + Proline. At BBCH 68 Carax included treatments reduced LAI compared with BBCH 62.

Table 29: Effect of fungicides and growth regulator on leaf area index (LAI) at different growth stages in GI and plant height of rapeseed under two levels of nitrogen at GI and RH 2008-09

Treatments[1)]	Giessen								RH
	LAI							Plant height (cm)	Plant height (cm)
	BBCH 54	BBCH 58	BBCH 68	BBCH 72	BBCH 80	BBCH 84	BBCH 86		
1	3.29_{b}	5.08_{bc}	7.01_{bc}	6.06_{bcde}	4.66_{de}	3.67	2.63	154.9_{abc}	174.9_{a}
2	3.58_{a}	5.53_{a}	7.40_{a}	5.86_{de}	4.63_{e}	3.73	2.68	155.1_{abc}	174.5_{a}
3	3.26_{b}	5.13_{ab}	7.10_{abc}	6.06_{bcde}	4.54_{e}	3.51	2.83	152.8_{abcd}	173.3_{ab}
4	3.29_{b}	5.11_{ab}	6.97_{bc}	5.96_{cde}	4.80_{bcde}	3.63	2.88	157.6_{a}	174.2_{ab}
5	3.01_{bc}	4.70_{bcd}	6.78_{cd}	5.75_{e}	4.75_{cde}	3.85	2.73	148.0_{bcd}	166.4_{def}
6	3.10_{bc}	4.64_{cd}	6.93_{bcd}	6.41_{ab}	4.72_{cde}	3.80	2.81	145.7_{d}	165.2_{ef}
7	3.21_{b}	5.02_{bcd}	7.01_{bc}	5.98_{cde}	4.63_{e}	3.69	2.70	154.9_{abc}	166.7_{def}
8	2.84_{c}	4.64_{cd}	6.90_{bcd}	6.30_{abc}	4.95_{abcd}	4.06	3.01	145.3_{d}	166.4_{def}
9	3.00_{bc}	4.62_{d}	7.18_{ab}	6.39_{ab}	4.99_{abc}	3.82	2.90	150.4_{abcd}	165.6_{ef}
10	3.11_{bc}	4.94_{bcd}	7.09_{abc}	6.49_{a}	5.11_{a}	3.87	2.76	147.5_{cd}	173.0_{abc}
11	3.14_{b}	4.76_{bcd}	6.92_{bcd}	6.36_{ab}	5.05_{ab}	3.86	3.07	148.4_{bcd}	163.8_{f}
12	3.03_{bc}	5.14_{ab}	6.58_{d}	6.19_{abcd}	4.68_{de}	3.80	2.74	156.9_{ab}	171.2_{abc}
13	3.17_{b}	5.09_{ab}	7.01_{bc}	6.18_{abcd}	4.98_{abc}	3.66	2.93	145.8_{d}	166.4_{def}
14	3.26_{b}	5.07_{bc}	6.73_{cd}	6.24_{abc}	4.73_{cde}	3.70	2.70	151.4_{abcd}	170.3_{bcd}
15	3.13_{b}	4.83_{bcd}	6.85_{bcd}	6.13_{abcd}	4.72_{cde}	3.71	2.82	147.4_{cd}	169.1_{cde}
Fu. ($LSD_{0.05}$)	**0.27**	**0.44**	**0.37**	**0.37**	**0.29**	**ns**	**ns**	**8.98**	**3.97**
N_1	3.23_{a}	5.16_{a}	7.15_{a}	6.29_{a}	4.92_{a}	3.93_{a}	2.82	150.8	169.9
N_2	3.10_{b}	4.75_{b}	6.78_{b}	6.02_{b}	4.67_{b}	3.59_{b}	2.81	150.8	168.9
N ($LSD_{0.05}$)	**0.10**	**0.16**	**0.13**	**0.14**	**0.11**	**0.12**	**ns**	**ns**	**ns**
Fu.x N ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

[1)] **1.** Control, **2.** $Caramba_{1st}$, **3.** $Folicur_{1st}$, **4.** $Moddus_{1st}$, **5.** $Caramba_{2nd}$, **6.** $Folicur_{2nd}$, **7.** $Moddus_{2nd}$, **8.** $Caramba_{2nd}$ + Cantus $Gold_{3rd}$, **9.** $Folicur_{2nd}$ + Cantus $Gold_{3rd}$, **10.** $Moddus_{2nd}$ + Cantus $Gold_{3rd}$, **11.** $Caramba_{2nd}$ + $Moddus_{2nd}$ + Cantus $Gold_{3rd}$, **12.** $Carax_{2nd}$ + $Proline_{3rd}$, **13.** $Carax_{2nd}$ + $Ortiva_{3rd}$, **14.** $Toprex_{2nd}$ + $Proline_{3rd}$, **15.** $Toprex_{2nd}$ + $Ortiva_{3rd}$. **N_1**= 270 kg/ha **N_2**= 210 kg/ha

Maximum LAI recorded from autumn applied and Cantus Gold included treatments at BBCH 68 by other treatments. Autumn applied Caramba (no 2) led to maximum value of LAI from green floral bud stage (BBCH 56) to pod development stage (BBCH 68) over other fungicidal treatments. However, LAI was reduced rapidly in control, autumn applied plots and only spring applied plots compared with double applied plots after BBCH 68. After 2 weeks of 3rd application at BBCH 72 LAI was significantly influenced by fungicidal treatments. At this stage all double applied treatments led to higher LAI compared with autumn and spring applied treatments including control. Combination of growth regulator (Moddus) with Cantus Gold (no 10) gave maximum value of LAI (6.49) which was statistically similar with that of all other double applied treatments and significantly higher than that of control, autumn and spring applied treatments with the exception of spring applied Folicur (no 6) at BBCH 72.

Fungicidal treatments did not show significant differences regarding LAI at BBCH 76. Contrary to that it was found that the later application of fungicides (BBCH 80) altered LAI significantly. LAI increased prominently when strobilurin fungicide (Cantus Gold) was applied in combination with triazole and growth regulator (no 8 to 11) at BBCH 80, compared with especially control and single treated plots (no 1 to 7). Maximum LAI was noted at BBCH 80 from Moddus + Cantus Gold treatment which was significantly higher from single applied including control treatments (no 1 to 7) and double applied treatments (no 13, 14 and 15), and it was statistically similar with that of all other treatments.
LAI was not affected significantly at latest times of measurements (BBCH 84, BBCH 86) by the application of fungicides. These measurements showed that LAI was reduced so quickly after BBCH 65 from control as well as Folicur and Caramba included treatments, while Cantus Gold included treatments (no 8 to 11) maintained higher LAI for longer time compared with other treatments. Higher level of nitrogen increased LAI significantly. Interaction between fungicides and nitrogen was found to be non significant at all growth stages of measurement.

Plant height

Plant height (PH) was significantly altered by the application of fungicides at both experimental stations during 2009 (Table 29). In Giessen, autumn applied Moddus (no 4) led to maximum PH (157.6 cm) which was statistically similar with that of all autumn applied, spring alone applied Moddus (no 7) and double applied treatments (no 9, 12 and 14), while it was significantly higher than that of all other fungicide treatments. Among alone spring applied treatments, Folicur induced lowest value of PH (145.7 cm) which was statistically at par with alone spring applied Caramba and significantly lower with respect to alone spring application of Moddus in Giessen. Among double applied treatments (no 8 to 12) minimum value of PH (145.3 cm) was recorded in case of application of Caramba + Cantus Gold (no 8) and was significantly lower than that of Carax + Proline (156.9 cm), while it was similar with all other double applied treatment including control. In RH untreated plants attained maximum PH (174.9 cm) which was statistically same with all autumn applied treatments (no 2 to 4) and double applied treatments (no 10 and 12), while this value of control was significantly higher than that of all other fungicidal treatments. Inclusion of Moddus in the mixture of Caramba and Cantus Gold (treat. no 11) led to minimal PH (163.8 cm) which was significantly lower than all autumn applied and control treatments (no 1 to 4) and double applied treatments (no 10, 12, 14 and 15), and it was statistically similar with all remaining double applied and alone spring applied treatments in RH. PH was statistically at par among each other in spring alone applied treatments (no 5 to 7) at RH. Nitrogen levels did not change the PH of rapeseed significantly at both stations. Interaction between fungicides and nitrogen was found to be non significant for PH at both station.

Seed yield components

Application of fungicides did not influence morphological parameters significantly during this experiment in Giessen (Table 30). Spring alone application of Moddus (no 7) had positive influence to improve morphological parameters of winter rapeseed with respect to other treatments. Maximum pods per plant (388.8) were obtained by spring application of Moddus, while Folicur + Cantus Gold (no 9) led to minimum number of pods per plant (206.6) compared with other treatments. Folicur included treatments (no 3, 6 and 9) reduced pods per plant in comparison with control.

Table 30: Effect of fungicides and growth regulator on pods/plant (P/Plant), pod length (PL), seeds/pod (S/Pd), main-branches (MB) and sub-branches (SB) at Giessen 2008-09

Treatments[1)]	P/Plant	PL (cm)	S/Pd	MB	SB
1	305.4	8.3	28.0	6.1	8.4
2	338.9	8.3	27.5	7.1	9.6
3	277.9	8.2	26.6	6.7	8.4
4	340.8	8.1	25.4	7.0	8.1
5	336.6	7.8	26.1	7.2	8.1
6	221.9	8.1	25.0	6.3	4.7
7	388.8	8.4	27.2	7.8	13.0
8	226.8	8.3	24.9	6.3	5.4
9	206.6	8.3	28.1	5.3	4.1
10	309.3	8.1	24.7	6.8	8.0
11	295.9	7.8	27.8	6.9	7.4
12	369.8	8.2	28.5	7.4	10.6
13	247.9	8.1	24.8	7.2	5.3
14	230.7	8.0	26.8	5.8	6.6
15	255.6	8.2	25.6	7.0	6.1
Fu. ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**ns**	**ns**
N_1	304.0	8.1	25.6b	7.1	8.2a
N_2	276.4	8.2	27.3a	6.4	6.9b
N ($LSD_{0.05}$)	**ns**	**ns**	**1.1**	**ns**	**0.62**
Fu.xN ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**ns**	**ns**

[1)] **1.** Control, **2.** $Caramba_{1st}$, **3.** $Folicur_{1st}$, **4.** $Moddus_{1st}$, **5.** $Caramba_{2nd}$, **6.** $Folicur_{2nd}$, **7.** $Moddus_{2nd}$, **8.** $Caramba_{2nd}$ + Cantus $Gold_{3rd}$, **9.** $Folicur_{2nd}$ + Cantus $Gold_{3rd}$, **10.** $Moddus_{2nd}$ + Cantus $Gold_{3rd}$, **11.**$Caramba_{2nd}$ + $Moddus_{2nd}$ + Cantus $Gold_{3rd}$, **12.** $Carax_{2nd}$ + $Proline_{3rd}$, **13.** $Carax_{2nd}$ + $Ortiva_{3rd}$, **14.** $Toprex_{2nd}$ + $Proline_{3rd}$, **15.** $Toprex_{2nd}$ + $Ortiva_{3rd}$. **N_1**= 270 kg/ha **N_2**= 210 kg/ha

Number of pods per plant enhanced non significantly with higher level of nitrogen over lower level. No interaction between fungicides and nitrogen for number of pods per plant. Pod length was not affected significantly by application of fungicides. Spring alone applied Moddus increased pod length to its maximum level (8.4 cm) while spring applied Caramba alone (no 5) as well as in combination with Moddus + Cantus Gold (no 11) led to minimum pod length (7.8 cm) over other treatments. Pod length did not alter significantly among nitrogen levels. There was no interaction between fungicides and nitrogen for pod length. Maximum seeds per pod (28.5) were recorded in case of application of Carax + Proline (no 12), whilst combination of Moddus with Cantus Gold (no 10) gave lowest number of seeds per pod (24.7).

Higher level of nitrogen significantly reduced number of seeds per pod compared with lower level of nitrogen. Interaction of fungicides and nitrogen was non significant.

Maximum number of main (7.8) and sub (13.0) branches was recorded in case of spring alone applied Moddus (no 7) over other treatments. Inclusion of Folicur to Cantus Gold reduced main and sub branches to its minimal levels 5.3 and 4.1 respectively compared with other treatments. Among autumn applied fungicides Caramba induced maximum number of main and sub-branches. However, minimum number of main and sub-branches were obtained in case of spring alone applied Folicur (no 6) compared with other spring alone applied treatments including control. Among double and triple applied treatments (no 8 to 15) performance of Carax + Proline (no 12) was best to increase main and sub-branches. Number of main-branches per plant did not alter significantly among higher and lower level of nitrogen. Nonetheless, number of sub-branches per plant was enhanced significantly by application of higher level of nitrogen over lower level. There was no interaction between fungicides and nitrogen regarding main and sub-branches per plant of rapeseed.

Diseases

Diseases were observed more severe at RH compared with Giessen. Maximum severity of diseases was observed in control and autumn applied plots compared with spring alone and double applied treatments at both research stations (Table 31). Double applied treatments (no 8 to 12) had better control against these diseases compared with all other fungicidal treatments. Incidence of sclerotinia was less compared with phoma at both stations. In Giessen Moddus + Cantus Gold (no 10) reduced the severity of both measured diseases to its minimal level compared with other treatments. In RH double applied treatments (no 8 to 12) proved best to control diseases and these did not show prominent difference among each other for observed diseases. Increase in nitrogen fertilization had no effect on severity of diseases at both stations.

Lodging

Maximum lodging was recorded from untreated control and autumn applied treatments compared with other fungicidal treatments at both stations (Table 31). Autumn application had no influence to reduce lodging like untreated plants. Double applied treatments produced more healthy plants which resisted against lodging compared with alone spring and autumn applied treatments including control at both stations. In Giessen Toprex included treatments (no 14 and 15) gave lowest values of lodging over other fungicidal treatments. Combination of Moddus with Caramba + Cantus Gold was observed best against lodging over other treatments in RH. Higher level of nitrogen slightly increased rate of lodging compared with lower level of nitrogen at both stations.

Table 31: Effect of fungicides and growth regulator on Lodging (Lod.), *Phoma lingam* (Phoma), *Sclerotinia sclerotiorum* (Sclero), TGW and seed yield of rapeseed under two levels of nitrogen at Giessen and RH 2008-09

Treatments[1)]	Giessen					Rauischholzhausen				
	Phoma (1-9)	Sclero (1-9)	Lod. (1-9)	TGW (g)	Yield (dt/ha)	Phoma (1-9)	Sclero (1-9)	Lod. (1-9)	TGW (g)	Yield (dt/ha)
1	4.1	1.9	4.2	4.54	52.6	6.5	2.7	3.2	4.49	62.3
2	3.8	1.9	3.5	4.60	54.4	6.9	2.6	3.5	4.51	62.3
3	3.7	1.7	4.1	4.54	52.0	6.2	2.2	3.5	4.42	61.6
4	3.9	1.7	3.8	4.50	51.7	6.6	2.7	2.3	4.41	61.5
5	3.1	1.6	3.1	4.52	53.4	4.3	2.0	3.2	4.45	62.5
6	3.3	1.4	3.0	4.54	54.3	4.4	1.7	2.7	4.41	61.7
7	3.5	1.3	3.3	4.58	53.0	4.1	1.8	2.6	4.41	62.4
8	3.3	1.3	3.2	4.45	51.9	3.8	1.3	2.4	4.42	64.0
9	3.1	1.3	2.9	4.53	56.5	3.5	1.3	2.5	4.43	62.5
10	2.6	1.1	3.2	4.48	55.2	3.3	1.4	2.4	4.45	61.5
11	3.0	1.3	2.7	4.51	57.8	3.5	1.6	2.0	4.37	63.5
12	3.1	1.3	2.3	4.68	53.8	3.6	1.6	2.4	4.47	63.5
13	3.0	1.4	2.5	4.62	53.0	3.7	1.4	2.6	4.42	62.1
14	3.1	1.3	2.0	4.66	55.7	3.7	1.5	2.6	4.44	61.5
15	3.2	1.4	2.1	4.59	52.3	3.1	1.3	2.5	4.47	63.1
Fu. ($LSD_{0.05}$)	-	-	-	**ns**	**ns**	-	-	-	**ns**	**ns**
N_1	3.3	1.4	3.1	4.56	54.4	4.5	1.8	2.8	4.45	63.3a
N_2	3.3	1.5	3.0	4.55	53.3	4.4	1.8	2.6	4.42	61.5b
N ($LSD_{0.05}$)	-	-	-	**ns**	**ns**	-	-	-	**ns**	**0.95**
Fu.x N ($LSD_{0.05}$)	-	-	-	**ns**	**ns**	-	-	-	**ns**	**ns**

[1)] **1.** Control, **2.** Caramba$_{1st}$, **3.** Folicur$_{1st}$, **4.** Moddus$_{1st}$, **5.** Caramba$_{2nd}$, **6.** Folicur$_{2nd}$, **7.** Moddus$_{2nd}$, **8.** Caramba$_{2nd}$ + Cantus Gold$_{3rd}$, **9.** Folicur$_{2nd}$ + Cantus Gold$_{3rd}$, **10.** Moddus$_{2nd}$ + Cantus Gold$_{3rd}$, **11.** Caramba$_{2nd}$ + Moddus$_{2nd}$ + Cantus Gold$_{3rd}$, **12.** Carax$_{2nd}$ + Proline$_{3rd}$, **13.** Carax$_{2nd}$ + Ortiva$_{3rd}$, **14.** Toprex$_{2nd}$ + Proline$_{3rd}$, **15.** Toprex$_{2nd}$ + Ortiva$_{3rd}$. **N_1**= 270 kg/ha **N_2**= 210 kg/ha

TGW

TGW was not affected significantly by the application of fungicides at both stations in 2009 (Table 31). Maximum TGW was recorded from Carax and Proline included treatments (no 12, 13 and 14), while the application of Moddus + Cantus Gold (no 10) was responsible to reduce TGW to its minimum level (4.48 g) than that of all other treatments in Giessen. Seeds of Moddus + Caramba + Cantus Gold treated plants exhibited minimum TGW (4.37 g), while alone autumn applied Caramba (no 2) gave maximum value of TGW (4.51 g) over other treatments in RH. A non significant increase in TGW was noted in case of higher level of nitrogen compared with lower level of nitrogen at both station. There was no interaction between fungicides and nitrogen regarding TGW at both stations.

Seed yield

Application of fungicides did not alter seed yield significantly at both stations. Higher seed yield was obtained from RH compared with Giessen (Table 31). Inclusion of Moddus in the mixture of Caramba + Cantus Gold (no 11) led to maximum seed yield (57.8 dt/ha) which was followed by Folicur + Cantus Gold (56.5 dt/ha) Toprex + Proline (55.7 dt/ha) and Moddus + Cantus Gold (55.2 dt/ha) and these were higher than that of all other treatments in Giessen. Among autumn and spring alone applied treatments application of Moddus induced minimum value of seed yield compared with other treatments in Giessen. Minimum seed yield (51.9 dt/ha) was recorded from Caramba + Cantus Gold treated plant which was lower compared with all other double applied, spring alone applied and control treatments in Giessen. Nonetheless, same treatment Caramba + Cantus Gold caused maximum seed yield (64.0 dt/ha) compared with all other fungicidal treatments in RH. All double applied treatments with the exception of treatment no 10 and 14 gave more seed yield than that of all other autumn and spring alone applied treatments including control in RH. In RH control treatment gave seed yield at the rate of 62.3 dt/ha which was higher than the seed yield from treatments no 3, 4, 5, 7, 10 and 14, while it was same or lower compared with other treatments. Seed yield was affected non significantly among nitrogen levels in Giessen. Nonetheless, higher level of nitrogen was significantly increased seed yield over lower level in RH. Interaction of fungicides and nitrogen was found to be non significant for seed yield at both stations.

4.6.2 Quality parameters

Oil content

Application of fungicides did not alter oil content in the seeds of rapeseed significantly in Giessen (Table 32). Nonetheless, oil content was affected significantly in RH. Application of Moddus in combination with Caramba + Cantus Gold produced maximum seed yield (57.8 dt/ha) as well as higher oil content (47.5%) over other treatments in Giessen. Autumn applied Caramba also produced same value of oil content (47.5%) which was followed by control (47.4%) and autumn alone applied Folicur (47.3%) which were higher than that of all other treatments in Giessen. Application of Moddus reduced oil content compared with other treatments in both autumn and spring alone applied and control treatments (no 1 to 7) in Giessen. Application of Toprex + Ortiva gave lowest oil content (46.1%) compared with other treatments in Giessen. Combination of triazole fungicides (Toprex + Proline) and control exhibited lowest oil content (47.0%) which was statistically at par with spring alone applied Moddus, while it was significantly lower than that of all other fungicidal treatments in RH. Autumn and spring alone applied treatments gave statistically similar values of oil content among each other. Statistical similar oil content was obtained among double applied treatments with the exception of Toprex + Proline in RH. Higher level of nitrogen decreased oil content non significantly compared with lower level of nitrogen at both stations. Interaction between fungicides and nitrogen was found to be significant for oil content at both experimental stations during this experiment.

Glucosinolates

Glucosinolate content (GSL) in the seeds of winter rapeseed did not alter significantly by the application of fungicides at both stations in 2009 (Table 32). Fungicidal treatment Moddus + Caramba + Cantus Gold which gave maximum seed yield as well as oil content, while it reduced GSL to its minimal levels 13.2 mmol/g which was lowest than that of all other fungicide treatments in Giessen. Untreated seeds gave maximum value of GSL (14.5 mmol/g) compared with other treatments in Giessen. Alone application of Folicur and Moddus in autumn and spring respectively reduced GSL over other respective treatments. Among double applied treatments Caramba + Cantus Gold (no 8) led to maximum GSL (14.4 mmol/g) in Giessen. In RH it was noted that Moddus included treatments (no 4, 7, 10 and 11) gave minimal value of GSL during this experiment. Among Moddus included treatments treatment no 8 exhibited lowest GSL (12.0 mmol/g) compared with all other fungicidal treatments in RH. Maximum GSL 14.1 and 13.9 mmol/g was reported from Proline included treatments 12 and 14 respectively which were higher than that of all other treatments in RH. Alone application of Folicur gave maximal GSL in autumn and spring alone applied treatments in RH. Among double applied treatments performance of treatment no 11 was optimal to reduce GSL to its minimal level (12.6 mmol/g) in RH. GSL did not show significant differences among nitrogen levels at both stations. Higher level of nitrogen increased GSL compared with lower level of nitrogen at both stations. There was no interaction between fungicides and nitrogen regarding GSL at both stations.

Protein content

Fungicides and growth regulator did not alter protein content in the seeds of winter rapeseed significantly at both experimental stations (Table 32). In Giessen same combination of Moddus + Caramba + Cantus Gold (no 11) which reduced GSL and also responsible to gave lowest protein content (17.8%) compared with other treatments. Maximum protein content (18.6%) was recorded from seeds of control, autumn applied Moddus and Caramba + Cantus Gold in comparison with other treatments in Giessen. Moddus in autumn and Caramba in spring alone applied treatments produced highest protein content, while Folicur led to least protein content among alone applied treatments (no 2 to 6) over others in Giessen. Results revealed that application of Caramba in combination with Cantus Gold (treat no 8) led to minimal protein content (17.1%) over other treatments in RH. Proline included treatments 12 and 14 gave maximum values of protein content 18.4 and 18.1% respectively which were higher than that of all other fungicidal treatments in RH. Seeds of untreated plants attained 17.3% protein content which was lower than that of all spring alone applied treatments. Higher level of nitrogen increased protein content non significantly in comparison with lower level of nitrogen at both stations. Interaction between fungicides and nitrogen was found to be non significant for protein content at both experimental stations.

Table 32: Effect of fungicides and growth regulator on oil content, glucosinolates (GSL), protein content, FFA and PV of rapeseed under two levels of nitrogen at Giessen and RH 2008-09

Treatments[1)]	**Giessen**					**Rauischholzhausen**				
	Oil %	**GSL mmol/g**	**Protein %**	**FFA %**	**PV meq/kg**	**Oil %**	**GSL mmol/g**	**Protein %**	**FFA %**	**PV meq/kg**
1	47.4	14.5	18.6	1.60	10.8	47.0_{c}	13.3	17.3	1.03_{bcd}	9.6_{a}
2	47.5	14.4	18.4	1.41	12.4	48.4_{a}	13.2	17.2	0.89_{d}	8.5_{abcde}
3	47.3	13.8	18.0	1.64	11.7	48.2_{a}	13.5	17.5	0.95_{cd}	8.9_{abc}
4	46.9	14.1	18.6	1.35	12.7	47.8_{ab}	13.2	17.3	0.91_{cd}	9.6_{a}
5	47.1	14.1	18.5	1.48	10.6	48.3_{a}	13.1	17.6	0.99_{bcd}	8.7_{abcd}
6	47.2	13.7	18.1	1.48	10.3	48.4_{a}	13.3	17.6	0.96_{cd}	6.5_{f}
7	46.4	13.5	18.2	1.47	11.2	47.7_{abc}	12.0	17.5	0.99_{bcd}	6.9_{def}
8	46.3	14.4	18.6	1.53	9.4	47.8_{ab}	13.1	17.9	1.13_{ab}	6.8_{def}
9	47.0	14.2	18.5	1.59	11.2	48.3_{a}	13.3	17.1	1.10_{abcd}	6.7_{ef}
10	47.1	14.0	18.4	1.60	8.8	47.8_{ab}	13.0	17.9	1.12_{abc}	7.4_{cdef}
11	47.5	13.2	17.8	1.59	10.8	48.1_{ab}	12.6	17.3	1.03_{bcd}	5.7_{f}
12	46.9	14.1	18.2	1.43	10.8	47.4_{bc}	14.1	18.4	1.32_{a}	9.5_{ab}
13	46.7	13.2	18.0	1.49	10.5	48.1_{ab}	13.2	17.4	1.03_{bcd}	8.9_{abc}
14	46.9	13.5	18.3	1.55	8.5	47.0_{c}	13.9	18.1	1.20_{ab}	7.6_{bcdef}
15	46.1	14.3	18.3	1.57	13.1	47.9_{ab}	13.1	17.5	1.08_{bcd}	9.0_{abc}
Fu. ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**ns**	**ns**	**0.73**	**ns**	**ns**	**1.86**	**0.23**
N_1	46.8	14.2	18.7	1.61_{a}	11.6_{a}	47.8	13.5	17.9	1.08_{a}	8.4
N_2	47.1	13.6	17.9	1.43_{b}	10.1_{b}	47.9	12.9	17.2	1.02_{b}	7.7
N ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**0.10**	**1.25**	**ns**	**ns**	**ns**	**0.68**	**ns**
Fu.x N ($LSD_{0.05}$)	**1.43**	**ns**	**ns**	**ns**	**4.83**	**1.03**	**ns**	**ns**	**0.32**	**2.62**

[1)] **1.** Control, **2.** Caramba$_{1st}$, **3.** Folicur$_{1st}$, **4.** Moddus$_{1st}$, **5.** Caramba$_{2nd}$, **6.** Folicur$_{2nd}$, **7.** Moddus$_{2nd}$, **8.** Caramba$_{2nd}$ + Cantus Gold$_{3rd}$, **9.** Folicur$_{2nd}$ + Cantus Gold$_{3rd}$, **10.** Moddus$_{2nd}$ + Cantus Gold$_{3rd}$, **11.** Caramba$_{2nd}$ + Moddus$_{2nd}$ + Cantus Gold$_{3rd}$, **12.** Carax$_{2nd}$ + Proline$_{3rd}$, **13.** Carax$_{2nd}$ + Ortiva$_{3rd}$, **14.** Toprex$_{2nd}$ + Proline$_{3rd}$, **15.** Toprex$_{2nd}$ + Ortiva$_{3rd}$. **N_1**= 270 kg/ha **N_2**= 210 kg/ha

Free fatty acids

Concentration of free fatty acids (FFA) in the oil of rapeseed in Giessen was not affected significantly by the application of fungicides (Table 32). Nonetheless, FFA was significantly influenced among fungicidal treatments in RH. Higher concentration of FFA was recorded in Giessen compared with RH. Autumn alone applied Folicur and Moddus (no 3 and 4) gave most and least values of FFA 1.64 and 1.35% respectively compared with that of all other fungicidal treatments in Giessen. Lowest FFA (1.43%) was recorded in case of application of Carax + Proline in comparison with all other double applied treatments (no 8 to 15) in Giessen. Conversely, in RH maximum FFA (1.32%) was noted in the oil samples of Carax + Proline treated plants which was statistically similar and was followed by Toprex + Proline (1.20%), Caramba + Cantus Gold (1.13%) and Moddus + Cantus Gold (1.12%), while it was significantly higher than that of all other fungicidal treatments including control. FFA of autumn and spring alone applied treatments including control (1 to 7) showed no significant differences among each other in RH. Double applied treatments slightly improved FFA compared with single applied treatments including control in RH. FFA in the oil of rapeseed was enhanced significantly by the application of higher level of nitrogen over lower level at both locations. Interaction between fungicides and nitrogen was not observed for FFA in Giessen. However, interaction was significant regarding FFA in RH.

Peroxides value

In Giessen, peroxides value (PV) varied not significantly, while it was significantly affected in RH by application of fungicides (Table 32). Maximum PV (13.1 meq/kg) was recorded in case of application of Toprex + Ortiva, whereas combination of Toprex with Proline gave lowest PV (8.5 meq/kg) compared with all other fungicidal treatments in Giessen. Higher PV was observed after the application of Moddus among autumn and spring alone applied treatments including control in Giessen. Oil sample of control and autumn alone applied Moddus treated plants attained maximum PV (9.6 meq/kg) which were statistically at par with these treatments (no 2, 3, 4, 12, 13 and 15), and were significantly higher than that of remaining fungicidal treatments at RH. Application of Moddus alone in spring and its inclusion with Caramba + Cantus Gold gave minimal values of PV 6.5 and 5.7 meq/kg which were significantly lower than that of all autumn and spring alone applied Caramba and in double applied Carax and Ortiva included treatments including control, while these were statistically similar with that of all other fungicidal treatments in RH. PV was enhanced significantly in Giessen, while non significantly in RH by the application of higher level of nitrogen in comparison with lower level. Interaction between fungicides and nitrogen was found to be significant regarding PV at both stations.

Saturated fatty acids

Saturated fatty acid (palmitic acid) was significantly influenced in Giessen, while it was affected non significantly in RH by the application of fungicides (Table 33). Maximum concentration of palmitic acid (4.54%) was observed in case of Moddus + Caramba + Cantus Gold (no 11) which was significantly higher than that of all autumn alone applied, control and spring alone applied Folicur, while it was statistically at par with that of all other fungicidal treatments in Giessen. Oil samples of double applied treatments (no 8 to 15) exhibited statistically non significant concentration of palmitic acid among each other in Giessen. There was not a prominent change in the concentration of palmitic acid by the application of fungicides in RH. Different levels of nitrogen did not change palmitic acid significantly in Giessen. Nonetheless, palmitic acid was significantly influenced by the higher level of nitrogen over lower level in RH. Significant interaction between fungicides and nitrogen was observed regarding palmitic acid in both experimental locations.

Table 33: Effect of fungicides and growth regulator on the concentration of major fatty acids of rapeseed oil under two levels of nitrogen at Giessen and RH 2008-09

Treatments[2)]	**Giessen**				**Rauischholzhausen**			
	C16:0[1)]	**C18:1**	**C18:2**	**C18:3**	**C16:0**	**C18:1**	**C18:2**	**C18:3**
1	4.44$_{bcd}$	59.6	19.9$_{c}$	9.8	4.43	58.9$_{cde}$	19.5$_{bc}$	9.76$_{a}$
2	4.41$_{d}$	59.6	20.0$_{bc}$	10.0	4.41	59.4$_{ab}$	19.4$_{bc}$	9.73$_{a}$
3	4.42$_{cd}$	59.5	20.0$_{bc}$	9.9	4.44	59.2$_{bc}$	19.4$_{bc}$	9.71$_{a}$
4	4.42$_{cd}$	59.2	20.2$_{abc}$	9.5	4.45	59.3$_{abc}$	19.5$_{bc}$	9.66$_{ab}$
5	4.47$_{abcd}$	59.4	20.3$_{ab}$	9.9	4.47	59.5$_{ab}$	19.4$_{bc}$	9.66$_{ab}$
6	4.41$_{d}$	59.7	20.0$_{bc}$	9.9	4.45	59.4$_{ab}$	19.2$_{c}$	9.56$_{bcd}$
7	4.51$_{ab}$	59.4	20.4$_{a}$	10.1	4.49	59.5$_{ab}$	19.6$_{b}$	9.51$_{cd}$
8	4.52$_{ab}$	59.5	20.3$_{ab}$	10.0	4.43	59.3$_{abc}$	19.6$_{b}$	9.67$_{ab}$
9	4.48$_{abcd}$	59.5	20.2$_{abc}$	10.0	4.44	59.7$_{a}$	19.3$_{bc}$	9.55$_{bcd}$
10	4.53$_{a}$	59.4	20.4$_{a}$	10.0	4.39	59.3$_{abc}$	19.6$_{b}$	9.69$_{ab}$
11	4.54$_{a}$	59.4	20.3$_{ab}$	9.9	4.46	59.7$_{a}$	19.3$_{bc}$	9.44$_{d}$
12	4.51$_{ab}$	59.4	20.1$_{abc}$	10.0	4.39	59.1$_{bcd}$	19.6$_{b}$	9.65$_{abc}$
13	4.48$_{abcd}$	59.3	20.2$_{abc}$	9.9	4.47	58.6$_{ef}$	20.0$_{a}$	9.47$_{d}$
14	4.49$_{abcd}$	59.2	20.3$_{ab}$	10.1	4.48	58.4$_{f}$	20.2$_{a}$	9.62$_{abc}$
15	4.50$_{abc}$	59.3	20.2$_{abc}$	9.9	4.42	58.7$_{def}$	20.0$_{a}$	9.62$_{abc}$
Fu. ($LSD_{0.05}$)	**0.08**	**ns**	**0.31**	**ns**	**ns**	**0.45**	**0.31**	**0.14**
N_1	4.47	59.6$_{a}$	20.1$_{b}$	10.1$_{a}$	4.47$_{a}$	59.6$_{a}$	19.2$_{b}$	9.65$_{a}$
N_2	4.48	59.3$_{b}$	20.3$_{a}$	9.8$_{b}$	4.41$_{b}$	58.8$_{b}$	19.9$_{a}$	9.59$_{b}$
N ($LSD_{0.05}$)	**ns**	**0.17**	**0.11**	**0.18**	**0.03**	**0.17**	**0.12**	**0.05**
Fu. x N ($LSD_{0.05}$)	**0.11**	**0.69**	**0.44**	**0.69**	**0.10**	**0.64**	**0.45**	**ns**

1) **1.** Control, **2.** Caramba$_{1st}$, **3.** Folicur$_{1st}$, **4.** Moddus$_{1st}$, **5.** Caramba$_{2nd}$, **6.** Folicur$_{2nd}$, **7.** Moddus$_{2nd}$, **8.** Caramba$_{2nd}$ + Cantus Gold$_{3rd}$, **9.** Folicur$_{2nd}$ + Cantus Gold$_{3rd}$, **10.** Moddus$_{2nd}$ + Cantus Gold$_{3rd}$, **11.**Caramba$_{2nd}$ + Moddus$_{2nd}$ + Cantus Gold$_{3rd}$, **12.** Carax$_{2nd}$ + Proline$_{3rd}$, **13.** Carax$_{2nd}$ + Ortiva$_{3rd}$, **14.** Toprex$_{2nd}$ + Proline$_{3rd}$, **15.** Toprex$_{2nd}$ + Ortiva$_{3rd}$. **N_1**= 270 kg/ha **N_2**= 210 kg/ha

2) C16:0 = Palmitic acid, C18:1 = Oleic acid, C18:2 = Linoleic acid,C18:3 = Linolenic acid

Unsaturated fatty acids

Oleic acid which is major unsaturated fatty acid in the oil of rapeseed was not affected significantly in Giessen, while it was significantly influenced in RH by the application of fungicides (Table 33). Spring alone application of Folicur gave maximum concentration oleic acid (59.7%) which was followed with 59.6% from control and autumn alone applied Caramba and these were higher than that of all other fungicide treatments in Giessen. Minimum oleic acid (59.2%) was recorded in case of Toprex + Proline over other fungicide treatments in Giessen. Like in Giessen here also in RH, Toprex + Proline gave lowest concentration of oleic acid (58.4%) which was statistically at par with Ortiva included treatments 13 and 15, while it was significantly lower than that of all other fungicidal treatments. Oil samples of spring alone applied and Cantus Gold included treatments (no 5 to 11) attained statistically same concentration of oleic acid in RH. Higher level of nitrogen significantly increased oleic acid over lower level at both station. Interaction between fungicides and nitrogen was found to be significant for oleic acid at both stations.

Linoleic acid (18:2) was influenced significantly by application of fungicide at both research stations. In Giessen, spring applied Moddus alone as well as in combination with Cantus Gold and in RH Toprex + Proline gave maximum concentrations of linoleic acid 20.4 and 20.2% respectively in comparison with other fungicidal treatments. Minimum concentrations of linoleic acid 19.9 and 19.2% were recorded from control in Giessen and spring alone applied Folicur in RH respectively. In RH Toprex and Ortiva included treatments (no 13 to 15) gave significantly higher concentration of linoleic acid by all other fungicide treatments. Higher level of nitrogen significantly reduced linoleic acid compared with lower level at both stations. Interaction between fungicides and nitrogen was found to be significant for linoleic acid at both stations. Linolenic acid was not affected significantly in Giessen, while it was significantly influenced in RH by the application of fungicides. Higher level of nitrogen significantly enhanced linolenic acid compared with lower level of nitrogen at both stations. Interaction between fungicides and nitrogen was significant in Giessen and non significant in RH regarding linolenic acid.

4.7 Fungicide × Nitrogen Experiments 2009-10

4.7.1 Field parameters

Leaf area index (LAI)

LAI did not show significant differences in Giessen while it was significantly affected in RH by application of fungicides and growth regulator (Table 34). At BBCH 60 maximum LAI (7.16) was recorded from Moddus + Cantus Gold treated plots over other treatments in Giessen. At this stage in RH application of Toprex + Ortiva gave highest value of LAI (6.81) which was significantly higher than that of other treatments (no 2, 4, 5, 6, 9, 10 and 12), while it was statistically similar with that of all other fungicidal treatments. Spring alone application of Folicur led to minimal LAI values 6.56 and 5.91 from Giessen and RH respectively compared with that of all other fungicidal treatments at BBCH 60.

At BBCH 70, maximum LAI (6.33) was recorded from fungicidal treatment no 11 which was followed with 6.24 from treatment no 15 in Giessen. Spring alone application of Folicur (no 6) led to minimal LAI 5.73 and 5.41 in Giessen and RH respectively at BBCH 70. Combination of Moddus + Cantus Gold (no 10) gave maximum LAI (6.46) which was statistically at par with all double applied treatments (no 8 to 15) with the exception of Folicur + Cantus Gold (no 9) and significantly higher than that of all other treatments with the exception of autumn alone applied Moddus at BBCH 70 in RH. Double applied treatments produced higher LAI compared with single applied including control in RH at BBCH 70.

In Giessen maximum LAI (5.15) was recorded from spring alone applied Caramba (no 5) over other treatments at BBCH 80. This value of LAI was followed with 5.09 and 5.08 from fungicidal treatments no 10 and 11. In Giessen untreated plants attained minimum LAI (4.54) compared with other fungicidal treatments at BBCH 80. In RH 3rd measurement was made at BBCH 78 which showed double applied treatments (8 to 15) with the exception of treatment no 8 gave statistically non significant LAI. Minimum LAI 4.60, 4.63 and 4.73 were recorded from treatments no 1, 3 and 4 which were statistically similar among each other as well as with treatments 2, 6 and 8, while these were significantly lower than that of all other treatments. Higher level of nitrogen significantly increased LAI over lower level during all measurements at both experimental stations. There was no interaction between fungicides and nitrogen regarding LAI in all measurement at both experimental locations.

Table 34: Effect of fungicides and growth regulator on LAI at different growth stages, height of planting stand (PH) and height of main stem from soil surface to 1st internode (PH_1) of rapeseed under two levels of nitrogen at Giessen and RH 2009-10

Treatments[1)]	Giessen					Rauischholzhausen				
	LAI			PH (cm)	PH_1 (cm)	LAI			PH (cm)	PH_1 (cm)
	BBCH 60	BBCH 70	BBCH 80			BBCH 60	BBCH 70	BBCH 78		
1	6.70	5.98	4.54	144.8ab	54.4	6.38abc	5.96bc	4.60e	153.1ab	42.3
2	6.79	5.96	4.64	144.1ab	50.8	6.37bc	5.96bc	5.01bcde	154.4a	39.9
3	6.93	6.06	4.58	145.6a	50.2	6.48ab	5.78cd	4.63e	155.6a	44.4
4	6.79	5.87	4.62	142.2abc	51.3	6.21bcd	6.09abc	4.73e	153.1ab	41.5
5	6.88	6.21	5.15	139.1cdef	55.5	6.32bcd	5.82bcd	5.41ab	148.4cd	37.8
6	6.56	5.73	4.76	139.1cdef	51.6	5.91d	5.41d	4.79de	145.9d	41.4
7	6.81	6.11	5.03	131.9h	48.4	6.43ab	5.85bcd	5.26abcd	150.3bc	36.9
8	6.63	6.05	4.98	137.8defg	48.7	6.43ab	6.10abc	4.88cde	148.1cd	35.7
9	6.66	6.20	4.71	139.7cde	48.7	5.99cd	5.84bcd	5.28abc	146.9cd	38.5
10	7.16	6.21	4.98	135.0gh	53.8	6.27bcd	6.46a	5.33abc	152.2ab	38.2
11	7.09	6.33	5.09	138.4cdefg	50.4	6.44ab	6.29ab	5.58a	147.5cd	39.1
12	6.64	6.01	5.08	135.3fgh	51.1	6.21bcd	5.97abc	5.34abc	146.9cd	33.3
13	6.81	6.21	4.90	136.3efg	40.9	6.56ab	6.04abc	5.52a	149.4bcd	43.9
14	6.98	6.08	4.94	140.9bcd	47.4	6.45ab	6.18abc	5.49a	150.6bc	40.0
15	6.99	6.24	4.79	141.9abc	40.4	6.81a	6.27abc	5.61a	152.2ab	37.0
Fu. ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**3.92**	**ns**	**0.43**	**0.49**	**0.47**	**3.66**	**-**
N_1	6.97a	6.20a	5.01a	139.6	49.5	6.66a	6.19a	5.36a	151.3a	41.4
N_2	6.69b	5.96b	4.70b	139.3	49.6	6.04b	5.81b	4.96b	149.3b	37.3
N ($LSD_{0.05}$)	**0.15**	**0.13**	**0.17**	**ns**	**ns**	**0.16**	**0.18**	**0.17**	**1.34**	**-**
Fu.x N ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**-**

[1)] **1.** Control, **2.** Caramba$_{1st}$, **3.** Folicur$_{1st}$, **4.** Moddus$_{1st}$, **5.** Caramba$_{2nd}$, **6.** Folicur$_{2nd}$, **7.** Moddus$_{2nd}$, **8.** Caramba$_{2nd}$ + Cantus Gold$_{3rd}$, **9.** Folicur$_{2nd}$ + Cantus Gold$_{3rd}$, **10.** Moddus$_{2nd}$ + Cantus Gold$_{3rd}$, **11.** Caramba$_{2nd}$ + Moddus$_{2nd}$ + Cantus Gold$_{3rd}$, **12.** Carax$_{2nd}$ + Proline$_{3rd}$, **13.** Carax$_{2nd}$ + Ortiva$_{3rd}$, **14.** Toprex$_{2nd}$ + Proline$_{3rd}$, **15.** Toprex$_{2nd}$ + Ortiva$_{3rd}$. **N_1**= 270 kg/ha **N_2**= 210 kg/ha

Plant height

At BBCH 80, plant height (PH) of winter rapeseed was significantly affected by the application of fungicides at both experimental stations during this study in 2010 (Table 34). Maximum values of PH were recorded from control and autumn applied treatments (no 1 to 4) at both stations. In Giessen, maximum PH (145.6 cm) was found that autumn applied Folicur was statistically similar with that of all other autumn applied treatments, control as well as Toprex + Ortiva treatment, while it was significantly higher compared with all other fungicidal treatments. Maximum reduction in PH (131.9 cm) was recorded by spring alone application of Moddus which was statistically similar with treatments no 10 and 12, while it was significantly lower than that of all other fungicidal treatments in Giessen. Like in Giessen autumn alone applied Folicur also produced tallest plants in RH. This value of PH (155.6 cm) was statistically at par with other autumn applied treatments, control and double applied treatments (no 10 and 15), while it was significantly higher than that of all other fungicidal treatments. At both stations application of Toprex + Ortiva did not reduce PH like other double applied treatments. Minimal reduction in PH was recorded from spring alone applied treatments at both stations. PH was altered non significantly among nitrogen levels in Giessen. Nonetheless, higher level of nitrogen significantly increased PH compared with lower level in RH. There was no interaction between fungicides and nitrogen regarding PH at both experimental stations.

Height of main stem

Height of main stem from soil surface to 1^{st} internode (PH_1) was measured at maturity time from 4 replications in Giessen and from one replication in RH (Table 34). Results of PH_1 revealed that it was not affected significantly by the application of fungicides in Giessen. Spring alone applied Caramba gave maximum value of PH_1 (55.5 cm), while Ortiva included treatments 13 and 15 gave minimal values of PH_1 40.9 and 40.4 cm respectively compared with other treatments in Giessen. Autumn applied treatments gave lower PH_1 compared with control in Giessen. Among double applied treatments Moddus and Cantus Gold included treatments (no 10 and 11) increased PH_1 in Giessen. PH_1 was not altered significantly among nitrogen levels in Giessen. Interaction between fungicides and nitrogen was found to be non significant for PH_1 in Giessen. Data of PH_1 from RH was not statistically analysed. Maximum value of PH_1 (44.4 cm) was recorded in case of autumn applied Folicur, while combination of Carax with Proline gave lowest value of PH_1 (33.3 cm) compared with other treatments in RH. Application of Folicur exhibited higher PH_1 in both autumn and spring alone applied treatments in RH. Among double applied treatments Carax + Proline gave higher value of PH_1 in RH. In both stations it was noted that taller plants attained higher PH_1 compared with dwarf plants. Higher level of nitrogen increased PH_1 compared with lower level of nitrogen in RH.

Seed yield components

Morphological parameters of rapeseed did not show obvious differences modified by application of fungicides and growth regulator at both research stations (Table 35). In Giessen maximum number of pods per plant (349.9) was obtained by the application of autumn applied Moddus (no 4) which was followed by Carax and Ortiva included treatments (no 12, 13 and 15) and these were higher than that of all other treatments. Moddus + Cantus Gold treated plants exhibited minimum number of pods per plant (224.6) compared with all other fungicidal treatments including control in Giessen. Higher level of nitrogen enhanced pods per plant non significantly in Giessen. No interaction was observed among the treatments for number of pods per plant in Giessen.

Table 35: Effect of fungicides and growth regulator on pods/plant (P/Plant), pod length (PL), seeds/pod (S/Pd), main-branches (MB) and sub-branches (SB) of rapeseed under two levels of nitrogen at Giessen and RH 2009-10

Treatments[1)]	Giessen					Rauischholzhausen				
	P/Plant	PL (cm)	S/pd	MB	SB	P/Pl	PL (cm)	S/pod	MB	SB
1	273.0	7.6	20.7	7.7	6.6	213.3	6.5	19.1	6.4	8.0
2	271.7	7.6	19.2	7.8	7.4	202.4	6.4	19.5	6.3	6.3
3	303.8	7.6	19.3	8.2	7.9	157.1	6.3	18.9	5.1	4.0
4	349.9	7.3	21.0	8.1	11.2	200.6	6.9	22.0	6.2	5.3
5	282.5	7.5	18.9	7.6	7.1	172.6	6.5	18.9	6.4	5.7
6	297.6	7.3	18.6	7.7	5.8	201.0	6.6	22.3	6.0	5.5
7	273.8	7.8	21.1	7.2	7.4	240.9	6.1	21.6	6.5	7.5
8	263.3	7.3	20.0	7.5	7.3	242.9	6.6	21.3	6.7	6.9
9	284.0	7.1	21.8	7.8	8.1	207.3	6.3	18.6	6.4	5.4
10	224.6	7.6	19.6	7.2	5.2	213.6	6.2	19.2	6.6	6.6
11	312.5	7.0	17.2	8.0	8.0	199.8	6.4	20.5	5.8	7.0
12	332.9	7.7	23.4	8.3	9.6	280.3	6.4	17.6	7.1	10.0
13	335.8	7.2	17.0	8.1	9.6	150.9	6.3	18.1	5.5	4.0
14	299.3	7.2	16.9	8.2	8.9	246.5	6.2	19.0	6.4	8.2
15	333.0	7.8	23.8	8.7	6.5	197.9	6.1	18.9	6.1	6.6
Fu. ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**ns**	**ns**	-	-	-	-	-
N_1	296.9	7.4	20.0	8.0	8.2	215.2	6.48	20.2	6.2	6.2
N_2	294.8	7.5	19.7	7.8	7.4	201.7	6.30	19.1	6.2	6.7
N ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**ns**	**ns**	-	-	-	-	-
Fu.x N ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**ns**	**ns**	-	-	-	-	-

1) **1.** Control, **2.** $Caramba_{1st}$, **3.** $Folicur_{1st}$, **4.** $Moddus_{1st}$, **5.** $Caramba_{2nd}$, **6.** $Folicur_{2nd}$, **7.** $Moddus_{2nd}$, **8.** $Caramba_{2nd}$ + Cantus $Gold_{3rd}$, **9.** $Folicur_{2nd}$ + Cantus $Gold_{3rd}$, **10.** $Moddus_{2nd}$ + Cantus $Gold_{3rd}$, **11.** $Caramba_{2nd}$ + $Moddus_{2nd}$ + Cantus $Gold_{3rd}$, **12.** $Carax_{2nd}$ + $Proline_{3rd}$, **13.** $Carax_{2nd}$ + $Ortiva_{3rd}$, **14.** $Toprex_{2nd}$ + $Proline_{3rd}$, **15.** $Toprex_{2nd}$ + $Ortiva_{3rd}$. **N_1**= 270 kg/ha **N_2**= 210 kg/ha

Combination of Carax with Proline gave maximum number of pods (280.3), while combination of Carax with Ortiva produced least number of pods per plant (150.9) than that of all other fungicidal treatments in RH. Application of Folicur and Caramba produced minimum number of pods among alone applied treatments including control in RH. Results revealed that higher level of nitrogen somehow increased number of pods per plant compared with lower level of nitrogen in RH. Pod length was not affected significantly by the application of fungicides in Giessen. Maximum pod length (7.8 cm) was recorded after spring alone applied Moddus and combination of Toprex with Ortiva compared with other fungicidal treatments in Giessen. Combination of two fungicides (Caramba and Cantus Gold) with Moddus (no 11) reduced pod length to its minimum level (7.0 cm) over other treatments in Giessen. Pod length was altered non significantly among the nitrogen levels in Giessen. Autumn applied Moddus produced maximum pod length (6.9 cm), whilst minimum pod length (6.1 cm) was obtained in case of Toprex + Ortiva over other treatments in RH. Maximum number of seeds per pod 23.8 and 22.3 were recorded from Toprex + Ortiva (no 15) in Giessen and spring alone applied Folicur (no 6) in RH respectively compared with other treatments. Combination of Proline with Toprex in Giessen and its combination with Carax in RH gave minimum number of seeds per pod 16.9 and 17.6 respectively by other fungicidal treatments. There was slight increase in number of seeds per pod with higher level of nitrogen compared with lower level at both experimental stations.

Fungicidal treatments Toprex + Ortiva and autumn applied Moddus led to maximum number of main (8.7) and sub (11.2) branches respectively compared with other treatments in Giessen. Performance of these treatments was observed best to improve morphological parameters in Giessen. Application of Carax + Proline gave maximum number main (7.1) and sub (10.0) branches, while minimum number of main (5.1) and sub (4.0) branches were recorded in case of autumn applied Folicur over other treatments in RH. Nitrogen levels did not change number of main and sub-branches per plant prominently at both stations. There was no interaction between fungicides and nitrogen regarding seed yield components at Giessen.

Diseases

Severity of Phoma was on higher level compared with Sclerotinia at both stations (Table 36). More incidences of observed diseases were recorded in RH compared with Giessen during this experiment. Rate of Phoma was ranged from 2.9 to 3.6 in Giessen, while it was varied from 3.7 to 6.1 in RH among fungicidal treatments. In Giessen there was not an obvious difference in control of both diseases among fungicidal treatments. Maximum incidence of Phoma (3.6) was recorded from untreated Control plots over other treatments in Giessen. Control and autumn applied treatments (no 1 to 4) subjected to maximum attack of Phoma compared with other fungicidal treatments in RH. Among spring alone applied treatments maximum infection of Phoma was noted in case of Moddus compared with other treatments at both stations. Application of Toprex + Ortiva gave best control against Phoma over all other fungicidal treatments in RH. Severity of Sclerotina ranged from 1.4 to 2.3 in Giessen and from 1.7 to 3.6 among fungicidal treatments in RH. Attack of Sclerotina was severe in control and autumn applied plots like Phoma compared with other treatments at both experimental locations. Alone application of Moddus during autumn and spring did not show better response against Sclerotina. Performance of Toprex + Ortiva was observed best against these diseases compared with other fungicidal treatments in RH. Double applied treatments (no 8 to 15) reduced incidence of both diseases compared with alone applied treatments including control (no 1 to 7) at both stations. At both experimental stations negligible effect of nitrogen levels was observed on the incidence of disease.

Table 36: Effect of fungicides and growth regulator on Lodging (Lod.), *Phoma lingam* (Phoma), *Sclerotinia sclerotiorum* (Sclero), TGW and seed yield of winter rapeseed under two levels of nitrogen at Giessen and RH 2009-10

Treatments[1)]	**Giessen**					**Rauischholzhausen**				
	Phoma (1-9)	**Sclero (1-9)**	**Lod. (1-9)**	**TGW (g)**	**Yield (dt/ha)**	**Phoma (1-9)**	**Sclero (1-9)**	**Lod. (1-9)**	**TGW (g)**	**Yield (dt/ha)**
1	3.6	2.2	3.4	4.63ab	59.5	5.8	3.5	4.5	4.00abc	33.6
2	3.3	2.1	2.2	4.68a	62.3	5.9	3.1	4.0	3.94bcd	36.2
3	3.0	2.3	2.9	4.63ab	61.9	6.1	3.3	3.5	3.96bcd	37.8
4	3.1	1.9	2.8	4.65a	62.3	5.9	3.6	4.2	3.92bcd	36.0
5	3.2	1.7	3.0	4.51cd	62.0	5.2	2.4	2.9	4.01abc	36.9
6	2.9	1.6	2.7	4.67a	59.7	5.0	2.2	2.9	4.07ab	36.5
7	3.3	1.8	2.5	4.47d	61.2	5.7	3.0	3.0	3.94bcd	36.4
8	3.3	1.5	1.5	4.63ab	61.3	4.6	2.3	1.7	3.86cd	36.8
9	2.9	1.8	1.7	4.70a	62.5	4.3	2.0	2.0	4.13a	37.8
10	3.0	1.7	1.6	4.41d	64.5	5.0	2.1	1.6	4.05ab	37.2
11	3.0	1.5	1.5	4.52bcd	63.6	5.0	2.0	1.3	3.93bcd	37.7
12	2.9	1.5	1.9	4.61abc	62.3	4.6	2.1	1.8	4.05ab	35.6
13	3.2	1.5	1.7	4.69a	62.2	4.9	1.7	2.1	4.04ab	37.4
14	2.9	1.5	1.4	4.64a	63.1	4.6	2.0	2.1	3.84d	37.1
15	3.0	1.4	1.7	4.64a	60.3	3.7	1.8	1.8	3.92bcd	38.0
Fu. ($LSD_{0.05}$)	-	-	-	**0.11**	**ns**	-	-	-	**0.15**	**ns**
N_1	3.0	1.7	2.2	4.57b	62.4	4.9	2.4	2.7	3.95	37.6a
N_2	3.2	1.7	2.1	4.64a	61.5	5.3	2.5	2.6	4.00	35.9b
N ($LSD_{0.05}$)	-	-	-	**0.04**	**ns**	-	-	-	**ns**	**0.92**
Fu.x N ($LSD_{0.05}$)	-	-	-	**ns**	**ns**	-	-	-	**ns**	**ns**

[1)] **1.** Control, **2.** Caramba$_{1st}$, **3.** Folicur$_{1st}$, **4.** Moddus$_{1st}$, **5.** Caramba$_{2nd}$, **6.** Folicur$_{2nd}$, **7.** Moddus$_{2nd}$, **8.** Caramba$_{2nd}$ + Cantus Gold$_{3rd}$, **9.** Folicur$_{2nd}$ + Cantus Gold$_{3rd}$, **10.** Moddus$_{2nd}$ + Cantus Gold$_{3rd}$, **11.** Caramba$_{2nd}$ + Moddus$_{2nd}$ + Cantus Gold$_{3rd}$, **12.** Carax$_{2nd}$ + Proline$_{3rd}$, **13.** Carax$_{2nd}$ + Ortiva$_{3rd}$, **14.** Toprex$_{2nd}$ + Proline$_{3rd}$, **15.** Toprex$_{2nd}$ + Ortiva$_{3rd}$. **N_1**= 270 kg/ha **N_2**= 210 kg/ha

Lodging

Maximum lodging was found in control, in autumn and in spring alone applied plots over others at both stations (Table 36). Scale of lodging ranged from 1.4 to 3.4 in Giessen, while it varied from 1.3 to 4.5 in RH among fungicidal treatments. Untreated plants were heavily lodged at both stations. Double applied treatments (no 8 to 15) led to more healthy plants, which resist to lodging compared with other treatments at both research stations. Among double applied treatments Toprex + Proline (no 14) in Giessen and combination of Moddus with Caramba and Cantus Gold (no 11) in RH gave minimum rate of lodging 1.4 and 1.3 respectively. Higher level of nitrogen slightly increased rate of lodging compared with lower level of nitrogen at both stations.

TGW

Application of fungicides altered TGW significantly at both station during this experiment (Table 36). Spring application of Folicur in combination with Cantus Gold (no 9) produced highest TGW (4.70 g) which was significantly lower than that of spring alone applied Caramba and Moddus (no 5 and 7) and in double applied treatments Moddus + Cantus Gold and their combination with Caramba (no 10 and 11), while it was statistically at par with that of all other fungicidal treatments including control in Giessen. Like in Giessen same fungicidal treatment no 9 induced maximum value of TGW (4.13 g) which was significantly higher than autumn applied treatments (no 2 to 4), spring alone applied Moddus (no 7) and double applied treatments no 8, 11, 14 and 15, while it was statistically at par with all other fungicidal treatments including control in RH. Moddus + Cantus Gold in Giessen and Toprex + Proline in RH produced lowest values of TGW 4.41 and 3.84 g respectively over other treatments. Among spring alone applied treatments minimum TGW was recorded in case of application of Moddus with respect to others at both stations. In Giessen TGW was significantly influenced among nitrogen levels. Nonetheless, non significant variation was observed among nitrogen levels regarding TGW in RH. At both experimental stations interaction between fungicides and nitrogen was found to be non significant for TGW.

Seed yield

Seed yield of winter rapeseed was not affected significantly among fungicidal treatments during this experiment (Table 36). In Giessen maximum seed yield (64.5 dt/ha) was obtained in case of Moddus + Cantus Gold (no 10) which was followed by Moddus + Caramba + Cantus Gold (63.6 dt/ha) and Toprex + Proline (63.1 dt/ha) which were higher than that of all other fungicidal treatments. Fungicidal treatment Toprex + Ortiva led to maximal seed yield (38.0 dt/ha) over all other fungicidal treatments in RH, while same treatment gave lowest seed yield (60.3 dt/ha) among double applied treatments (no 8 to 15) in Giessen. Alone application of Folicur in Giessen and Moddus in RH led to minimal values of seed yield among both autumn and spring alone applied treatments (no 2 to 7). Minimum seed yield 59.5 and 33.6 dt/ha was recorded from untreated plots over other treatments in Giessen and RH respectively. Autumn alone application of Folicur (no 3) gave maximum seed yield (37.8 dt/ha) among single applied and control treatments (no 1 to 7) in RH. Inclusion of Cantus Gold to Moddus as well as with Moddus + Caramba led to increase seed yield compared with its combination with Folicur and Caramba in Giessen and with the exception of Folicur + Cantus Gold in RH. Performance of Toprex + Ortiva in

Giessen and Carax + Proline in RH was not efficient to increase seed yield in comparison with double applied treatments. Proline in combination with Toprex induced higher seed yield compared with its inclusion to the Carax at both experimental locations during this experiment. Higher level of nitrogen increased seed yield non significantly in Giessen, while it was influenced significantly in RH over lower level of nitrogen. At both stations, interaction between fungicides and nitrogen was found to be non significant regarding seed yield.

4.7.2 Quality parameters

Oil content

Oil content in the seeds of winter rapeseed was significantly affected by the application of fungicides at both stations (Table 37). Maximum accumulation of oil content (47.0%) was recorded by the application of Carax in combination with Ortiva (no 13) which was statistically at par and followed with 46.9% from Proline included treatments (no 12 and 14), 46.8% from autumn alone applied Moddus (no 4), 46.7% from Moddus + Caramba + Cantus Gold (no 11), 46.6% from Folicur + Cantus Gold (no 9) and 46.4 % from Moddus + Cantus Gold (no 10), while it was significantly higher than that of all other fungicidal treatments in Giessen. Carax included treatments 12 and 13 exhibited maximum oil content (46.5%) in the seeds which was significantly higher than that of control, all autumn and spring alone applied treatments and in double applied combination of Folicur and Caramba with Cantus Gold, and it was statistically similar with that of all other double applied treatments in RH. Autumn alone application of Folicur in Giessen and Caramba in RH induced minimum value of oil content 45.7% and 45.0% respectively. In Giessen, among single applied treatments (no 2 to 7) with the exception of autumn applied Moddus attained significantly same values of oil content compared with control. In RH, all autumn and spring alone applied treatments including control showed statistically similar values of oil content. Among double applied treatments Toprex + Ortiva and Caramba + Cantus Gold led to minimal oil content of 46.0% and 46.1% respectively over others in Giessen. Lowest value of oil content (45.1%) was recorded from the seeds of Folicur + Cantus Gold which was statistically similar with Caramba + Cantus Gold and Moddus + Caramba + Cantus Gold and it was significantly lower than others among double applied treatments (8 to 15) in RH. Results revealed that higher level of nitrogen significantly reduced oil content compared with lower level of nitrogen at both stations. Interaction between fungicides and nitrogen was found to be significant for oil content in Giessen. Nonetheless, no interaction was observed in RH.

Glucosinolates

Application of fungicides altered the contents of glucosinolates (GSL) in the seeds significantly only in Giessen but not in RH (Table 37). Spring application of Moddus in combination with Cantus Gold induced lowest value of GSL (13.8 mmol/g) which was statistically similar with that of other spring alone applied Moddus (no 7), and it was significantly lower than that of all other fungicidal treatments including control in Giessen. Maximum GSL (16.9 mmol/g) was recorded in case of spring alone application of Folicur (no 6) which was significantly higher than that of spring applied Moddus included treatments (no 7, 10 and 11) and double applied Toprex + Ortiva, while it was statistically at par with other treatments including control in Giessen. Spring applied Moddus treatments in RH also reduced GSL compared with other treatments. Application of Toprex + Ortiva somehow reduced GSL compared with control at both stations. GSL was enhanced significantly with higher level of nitrogen compared with lower level of nitrogen at both stations. There was no interaction between fungicides and nitrogen regarding GSL at both stations.

Table 37: Effect of fungicides and growth regulator on oil content, glucosinolates, protein content, FFA and PV of rapeseed under two levels of nitrogen at Giessen and RH 2009-10

Treatments[1)]	Giessen					Rauischholzhausen				
	Oil %	GSL mmol/g	Protein %	FFA %	PV meq/kg	Oil %	GSL mmol/g	Protein %	FFA %	PV meq/kg
1	45.8_{d}	16.2_{abc}	18.3	0.95_{b}	4.93_{bc}	45.4_{cd}	15.3	18.1_{abc}	0.92_{abc}	4.05
2	46.1_{bcd}	15.7_{abc}	18.2	0.94_{b}	5.25_{ab}	45.0_{d}	15.7	18.0_{abc}	0.81_{c}	4.09
3	45.7_{d}	15.9_{abc}	18.5	0.90_{b}	6.02_{a}	45.4_{cd}	15.2	17.9_{bc}	0.84_{c}	3.88
4	46.8_{ab}	16.2_{abc}	18.3	0.92_{b}	4.64_{bcd}	45.5_{bcd}	15.5	17.7_{c}	0.89_{bc}	4.15
5	46.0_{cd}	16.6_{abc}	18.3	0.81_{b}	5.40_{ab}	45.3_{cd}	15.3	18.0_{abc}	0.94_{abc}	4.48
6	45.8_{d}	16.9_{a}	18.2	0.91_{b}	5.39_{ab}	45.4_{cd}	15.3	18.4_{ab}	0.94_{abc}	3.74
7	46.1_{bcd}	14.3_{de}	17.9	0.84_{b}	5.97_{a}	45.3_{cd}	14.3	17.9_{bc}	0.86_{bc}	4.01
8	46.1_{bcd}	16.6_{abc}	18.3	0.91_{b}	4.40_{bcde}	45.6_{bcd}	14.8	18.1_{abc}	0.91_{abc}	4.11
9	46.6_{abc}	16.8_{ab}	18.4	1.00_{b}	3.71_{de}	45.1_{d}	15.7	18.5_{a}	1.04_{a}	4.24
10	46.4_{abcd}	13.8_{e}	17.9	0.81_{b}	5.38_{ab}	46.0_{abc}	15.1	17.8_{c}	0.93_{abc}	3.89
11	46.7_{abc}	15.3_{cd}	18.4	0.91_{b}	4.06_{cde}	45.7_{abcd}	14.2	17.7_{c}	0.98_{ab}	4.28
12	46.9_{a}	16.5_{abc}	18.6	0.98_{b}	3.46_{e}	46.5_{a}	15.1	17.6_{c}	0.81_{c}	4.08
13	47.0_{a}	16.2_{abc}	18.4	0.97_{b}	4.21_{cde}	46.5_{a}	15.0	18.1_{abc}	0.81_{c}	4.25
14	46.9_{a}	16.4_{abc}	18.6	1.01_{b}	4.15_{cde}	46.3_{ab}	15.0	18.1_{abc}	0.86_{bc}	3.87
15	46.0_{cd}	15.5_{bc}	18.5	1.45_{a}	3.76_{de}	46.3_{ab}	14.5	18.1_{abc}	0.92_{abc}	4.24
Fu. ($LSD_{0.05}$)	**0.75**	**1.35**	**ns**	**0.28**	**1.03**	**0.74**	**ns**	**0.47**	**0.13**	**ns**
N_1	46.1_{b}	16.4_{a}	18.8_{a}	1.03_{a}	4.49_{b}	45.3_{b}	15.5_{a}	18.3_{a}	0.96_{a}	3.75_{b}
N_2	46.6_{a}	15.5_{b}	17.9_{b}	0.87_{b}	4.94_{a}	46.1_{a}	14.6_{b}	17.7_{b}	0.83_{b}	4.43_{a}
N ($LSD_{0.05}$)	**0.27**	**0.49**	**0.25**	**0.10**	**0.38**	**0.27**	**0.36**	**0.17**	**0.05**	**0.17**
Fu.x N ($LSD_{0.05}$)	**1.06**	**ns**	**ns**	**ns**	**1.45**	**ns**	**ns**	**ns**	**ns**	**0.65**

[1)] **1.** Control, **2.** $Caramba_{1st}$, **3.** $Folicur_{1st}$, **4.** $Moddus_{1st}$, **5.** $Caramba_{2nd}$, **6.** $Folicur_{2nd}$, **7.** $Moddus_{2nd}$, **8.** $Caramba_{2nd}$ + Cantus $Gold_{3rd}$, **9.** $Folicur_{2nd}$ + Cantus $Gold_{3rd}$, **10.** $Moddus_{2nd}$ + Cantus $Gold_{3rd}$, **11.**$Caramba_{2nd}$ + $Moddus_{2nd}$ + Cantus $Gold_{3rd}$, **12.** $Carax_{2nd}$ + $Proline_{3rd}$, **13.** $Carax_{2nd}$ + $Ortiva_{3rd}$, **14.** $Toprex_{2nd}$ + $Proline_{3rd}$, **15.** $Toprex_{2nd}$ + $Ortiva_{3rd}$. **N_1**= 270 kg/ha **N_2**= 210 kg/ha

Protein content

Protein content in the seeds of winter rapeseed was not affected significantly by the applied fungicides in Giessen, while it was significantly altered in RH (Table 37). In Giessen, maximum protein content (18.6%) was recorded from Proline included treatments (no 12 and 14), whereas spring applied Moddus included treatments (no 7 and 10) led to lowest value of protein content (17.9%) over other treatments. In RH, minimum protein content (17.6%) was noted in case of Carax + Proline which was significantly lower than that of spring applied Folicur alone as well as in combination with Cantus Gold (no 6 and 9), while it was statistically at par with all other fungicidal treatments. Results of protein content at both stations revealed that application of Moddus had retarding effect on protein content compared with other fungicidal treatments. Higher level of nitrogen significantly increased protein content compared with lower level of nitrogen at both research stations. No interaction was observed between fungicides and nitrogen for protein content at both research stations.

Free fatty acids

Concentration of free fatty acids (FFA) in the oil of winter rapeseed was significantly influenced after application of fungicides at both research stations (Table 37). In Giessen, significant higher FFA (1.45%) was recorded from Toprex + Ortiva over all other treatments and FFA of other all treatments were statistically similar among each other. Carax included treatments (no 12 and 13) led to minimum FFA (0.81%) which was significantly lower than that of only Folicur + Cantus Gold (no 9), and was statistically same with all other treatments in RH. At both research stations, FFA was enhanced significantly with higher level of nitrogen compared with lower level of nitrogen. At both research stations interaction between fungicides and nitrogen was found to be non significant regarding FFA.

Peroxides value

Application of fungicides altered peroxides value (PV) in the oil of winter rapeseed significantly in Giessen and non significantly in RH (Table 37). In Giessen, application of Carax in combination with Proline improved the quality of rapeseed oil to reduce PV at its minimal level (3.46 meq/kg) which was statistically significantly lower than that control and all single applied treatments (no 1 to 7), while it was statistically similar with that of all other double applied treatments with the exception of Moddus + Cantus Gold (no 10) in Giessen. Maximum FFA (6.02 mequ/kg) was recorded in case of autumn alone application of Folicur which was significantly higher than that of control and autumn applied Moddus and all double applied treatments with the exception of Moddus + Cantus Gold (no 10), while it was statistically similar with that of all other fungicidal treatments in Giessen. Spring alone applied Caramba gave maximum PV (4.48 meq/kg) over other treatments in RH. Higher level of nitrogen significantly reduced PV over lower level of nitrogen at both stations. Interaction between fungicides and nitrogen was found to be significant for PV at both experimental locations.

Saturated fatty acids

Application of Moddus + Cantus Gold enhanced concentration of palmitic acid (4.66%) significantly compared with other treatments in Giessen (Table 38). Minimum concentration of palmitic acid (4.44%) was recorded from control which was statistically similar with that of all single applied treatments with the exception of spring alone applied Moddus (no 7) and in double applied Caramba + Cantus Gold (no 8), while it was significantly lower than that of all other fungicidal treatments in Giessen. Autunm and spring alone applied Moddus gave maximum value of palmitic acid (4.42%) which was statistically at par with all other single applied treatments and in double applied Caramba + Cantus Gold (no 10), while it was significantly higher than that of all other fungicidal treatments including control in RH. Minimum palmitic acid (4.34%) was recorded in case of Carax + Proline (no 12) which was not significantly differed from Control spring alone applied Folicur and Caramba and all other double applied treatments, while it was significantly higher than that of all other fungicidal treatments. In Giessen, Higher level of nitrogen significantly reduced palmitic acid over lower level. No interaction between fungicides and nitrogen for palmitic acid in Giessen. Nonetheless, significant interaction was observed in RH.

Unsaturated fatty acids

Unsaturated fatty acids (oleic, linoleic and linolenic acid) were significantly affected by the application of fungicides at both stations (Table 38). Maximum oleic acid (59.2%) was recorded in case of spring alone applied Folicur which was significantly lower than that of spring applied Moddus alone as well as in combination with Catus Gold (no 7 and 10) and Toprex included treatments (no 14 and 15), while it was statitically similar with that of all other fungicidal treatments in Giessen. Toprex + Ortiva in Giessen and spring alone applied Moddus in RH led to minimum concent of oleic acid 58.4 and 58.8% respectively over other treatments. Concentration of oleic acid from spring alone applied Moddus significantly lower than that of all other treatments in RH. All fungicidal treatments in RH showed statistically similar values of oleic acid with the exception of treatments no 2 and 10. Oleic acid increased significantly in RH and non significantly in Giessen with higher level of nitrogen over lower level. Interaction bteween fungicides and nitrogen was significant in Giessen and non significant in RH.

Spring application of Moddus alone as well as in combination with Cantus Gold led to maximum linoleic acid (20.3%) which was statistically same with that of Moddus + Caramba + Cantus Gold (no 11) and Toprex + Ortiva (no 15), while it was significantly higher than that of all other fungicidal treatments in Giessen. Significant higher concentration of linoleic acid (20.4%) was recorded in case of spring alone application of Moddus than other treatments in RH. At both stations autumn applied treatments including control reduced linoleic acid compared with other treatments. Concentration of linoleic acid was reduced significantly in Giessen and non significantly in RH with higher level of nitrogen over lower level. There was no interaction between fungicides and nitrogen for linoleic acid at both stations.

Table 38: Effect of fungicides and growth regulator on the concentration of major fatty acids of rapeseed oil under two levels of nitrogen at Giessen and RH 2009-10

Treatments[1]	**Giessen**				**Rauischholzhausen**			
	C16:0[2]	**C18:1**	**C18:2**	**C18:3**	**C16:0**	**C18:1**	**C18:2**	**C18:3**
1	4.44$_{f}$	58.8$_{abc}$	19.8$_{d}$	9.89$_{bc}$	4.35$_{cd}$	59.2$_{ab}$	20.0$_{bc}$	9.23$_{bc}$
2	4.49$_{def}$	59.0$_{ab}$	19.8$_{d}$	9.92$_{bc}$	4.39$_{abc}$	59.0$_{b}$	20.1$_{b}$	9.28$_{b}$
3	4.49$_{def}$	59.0$_{ab}$	19.9$_{cd}$	9.96$_{bc}$	4.40$_{ab}$	59.2$_{ab}$	20.0$_{bc}$	9.24$_{bc}$
4	4.48$_{ef}$	59.1$_{ab}$	19.8$_{d}$	9.93$_{bc}$	4.42$_{a}$	59.1$_{ab}$	20.0$_{bc}$	9.28$_{b}$
5	4.46$_{f}$	58.9$_{ab}$	19.9$_{cd}$	9.87$_{bc}$	4.38$_{abcd}$	59.2$_{ab}$	20.1$_{b}$	9.26$_{bc}$
6	4.46$_{f}$	59.2$_{a}$	19.8$_{d}$	9.86$_{bc}$	4.38$_{abcd}$	59.1$_{ab}$	20.0$_{bc}$	9.41$_{a}$
7	4.60$_{b}$	58.7$_{bc}$	20.3$_{a}$	9.69$_{d}$	4.42$_{a}$	58.8$_{c}$	20.4$_{a}$	9.27$_{bc}$
8	4.49$_{def}$	58.9$_{ab}$	20.0$_{bcd}$	9.88$_{bc}$	4.38$_{abcd}$	59.1$_{ab}$	20.1$_{b}$	9.19$_{cd}$
9	4.52$_{cde}$	58.8$_{abc}$	19.8$_{d}$	9.87$_{bc}$	4.36$_{bcd}$	59.2$_{ab}$	20.0$_{bc}$	9.31$_{b}$
10	4.66$_{a}$	58.7$_{bc}$	20.3$_{a}$	8.67$_{d}$	4.37$_{bcd}$	59.2$_{ab}$	20.0$_{bc}$	9.17$_{cde}$
11	4.56$_{bc}$	58.9$_{ab}$	20.1$_{abc}$	9.84$_{c}$	4.37$_{bcd}$	59.2$_{ab}$	20.1$_{b}$	9.10$_{de}$
12	4.53$_{cde}$	59.0$_{ab}$	20.0$_{bcd}$	9.97$_{bc}$	4.34$_{d}$	59.3$_{a}$	19.9$_{c}$	9.17$_{cde}$
13	4.53$_{cde}$	58.9$_{ab}$	20.0$_{bcd}$	9.99$_{b}$	4.35$_{cd}$	59.3$_{a}$	20.0$_{bc}$	9.16$_{cde}$
14	4.54$_{cd}$	58.7$_{bc}$	19.9$_{cd}$	9.98$_{b}$	4.35$_{cd}$	59.3$_{a}$	19.9$_{c}$	9.07$_{e}$
15	4.55$_{bc}$	58.4$_{c}$	20.2$_{ab}$	10.15$_{a}$	4.35$_{cd}$	59.1$_{ab}$	20.1$_{b}$	9.11$_{de}$
Fu. ($LSD_{0.05}$)	**0.05**	**0.41**	**0.24**	**0.13**	**0.12**	**0.22**	**0.16**	**0.11**
N_1	4.51$_{b}$	59.0	19.9$_{b}$	9.80$_{b}$	4.37	59.3$_{a}$	20.0	9.13$_{b}$
N_2	4.53$_{a}$	58.8	20.1$_{a}$	10.00$_{a}$	4.38	59.0$_{b}$	20.1	9.30$_{a}$
N ($LSD_{0.05}$)	**0.02**	**ns**	**0.09**	**0.05**	**ns**	**0.08**	**ns**	**0.04**
Fu.x N ($LSD_{0.05}$)	**ns**	**ns**	**ns**	**ns**	**0.07**	**0.31**	**ns**	**0.15**

[1] **1.** Control, **2.** Caramba$_{1st}$, **3.** Folicur$_{1st}$, **4.** Moddus$_{1st}$, **5.** Caramba$_{2nd}$, **6.** Folicur$_{2nd}$, **7.** Moddus$_{2nd}$, **8.** Caramba$_{2nd}$ + Cantus Gold$_{3rd}$, **9.** Folicur$_{2nd}$ + Cantus Gold$_{3rd}$, **10.** Moddus$_{2nd}$ + Cantus Gold$_{3rd}$, **11.** Caramba$_{2nd}$ + Moddus$_{2nd}$ + Cantus Gold$_{3rd}$, **12.** Carax$_{2nd}$ + Proline$_{3rd}$, **13.** Carax$_{2nd}$ + Ortiva$_{3rd}$, **14.** Toprex$_{2nd}$ + Proline$_{3rd}$, **15.** Toprex$_{2nd}$ + Ortiva$_{3rd}$. **N_1**= 270 kg/ha **N_2**= 210 kg/ha
[2] C16:0 = Palmitic acid, C18:1 = Oleic acid, C18:2 = Linoleic acid,C18:3 = Linolenic acid

Toprex + Ortiva (no 15) in Giessen and spring alone applied Folicur (no 6) in RH led to maximal concentration of linolenic acid 10.15 and 9.41% respectively which were significantly higher than that of all other fungicidal treatments. In Giessen, spring application of Moddus alone as well as in combination with Cantus Gold (no 7 and 10) attained minimum concentration of linolenic acid 9.69 and 8.67% respectively which were statistically same among each other but significantly lower than that of all other treatments. In RH, combination of Toprex with Proline gave minimal concentration of linolenic acid (9.07%) which was statistically at par with other all double applied treatments with the exception of Cantus Gold included treatments (no 8 and 9), while it was significantly lower than that of all other treatments. Higher level of nitrogen significantly reduced concentration of linolenic acid compared with lower level of nitrogen at both stations. Interaction between fungicides and nitrogen was found to be non significant in Giessen and significant in RH for linolenic acid.

5. DISCUSSION

5.1 Fungicide × Cultivar Experiments

The results of this study indicate that double applied fungicides increased leaf area index (LAI) of rapeseed by delaying senescence in comparison with alone application of triazole (Toprex) and strobilurin (Ortiva) fungicides as well as control treatment at the later stages of rapeseed in Giessen. Maximum LAI was recorded by application of Toprex (paclobutrazole & difenoconazole) at the rate of 0.5 L/ha in combination with Ortiva (azoxystrobin) at all growth stages rapeseed. This effect can be explained by prolonged photosynthetic duration of green tissues by Ortiva application at BBCH 65 as second application with triazole fungicides compared with its alone application. Similar results were recorded by Zhao et al. (2010) in wheat who explained the biochemical background of this effect that Ortiva application delayed senescence by enhancing antioxidative potential and protecting the plants from harmful active oxygen species.

During this study triazole included treatment (Folicur + Proline) reduced LAI among double applied treatments at later stages of rapeseed. Zhou and Leoul (1998) reported that application of triazole increased level of stress hormone abscisic acid (ABA) which favors senescence. Strobilurin was observed best as the second application at BBCH 65 to delay senescence compared with triazole.

Triazole and trinexapac are anti-gibberellins which improve stem stability by inhibiting intercalary growth which reduces the probability of lodging. Double applied treatments which had higher LAI also reduced lodging more than single applied fungicides. LAI is the ratio of green plant material that covers a square meter of land and has a direct influence on crop vigor, root development, carbohydrate storage and nutrient transport. Healthiness of rape plants were improved with increase of LAI and lodging was reduced considerably.

Height of planting stand had inverse relation with lodging which was confirmed by Armstrong and Nicol (1991). At both stations alone applied Ortiva and control which were severely lodged had minimum plant height in comparison with other treatments. Higher plant height with minimum lodging was recorded in case of Folicur + Proline over other treatments at both stations. Borovko (2008) observed same results by application of Folicur in combination with Moddus in spring rapeseed. Application of Ortiva in combination with Toprex produced healthy plants which resist to lodging than that of its alone application. At Giessen it was observed that by reducing the concentration of Toprex from 0.5 to 0.35 L/ha in combination with Ortiva increased lodging. Baylis and Wright (1990) also observed same results after applying paclobutrazole on winter rapeseed.

TGW is an important yield component and its value decides boldness of the seed. Application of fungicides altered TGW significantly at both stations. Heavily lodged plants of untreated plots attained lowest TGW at both stations. It can be explained that lodging gets worse the growing conditions for seed filling induced by reduced light impact and photosynthesis (Baylis and Hutley-Bull 1991). Severe lodging interferes with the transport of nutrients and moisture from the soil, and thus with storage in the developing seeds of rapeseed. Incomplete filling results in small seeds with lower oil and protein content and weight. TGW was lower at RH than that of Giessen. This can be explained by severe lodging at RH compared with Giessen.

At both stations performance of Caramba in combination with Cantus was consistent to enhance TGW, while alone application of Toprex reduced TGW among fungicidal treatments. Our findings are coincided with the investigations of Berry and Spink (2009) who reported that Caramba (metconazole) application in winter rapeseed enhanced TGW by increasing green area index and developing optimum size of the crop canopy which was better protected against lodging. Growth regulator Moddus included treatment attained maximum value of TGW and minimal lodging at Giessen, while at RH same treatment plots were lodged severely due to thunder storm at the time of maturity in response TGW was reduced. There is a negative relationship between lodging and TGW.

Combined application of triazole fungicides (Folicur + Proline) significantly increased TGW at both stations. At the same time this treatment decreased number of pods per main stem and increased number of seeds per stem compared. As number of pods were decreased then more assimilates were transferred towards lower number of pods which was associated with higher TGW than that of control. In both experiments LAI had direct relation with TGW of rapeseed which is supported with the investigation of Faraji (2011). LAI estimates total green canopy of the plant which is the only source of assimilates production for grain filling. Double applied treatments which attained highest LAI also having maximum TGW than that of control treatment. The reduction of TGW in case of cv. NK Fair was associated with higher plant height in comparison with cv. Elektra. Shorter plants receive equal and maximum light throughout the canopy and consequently bold seeds are produced (Zhou and Ye 1996).

Seed yield and its formation process depend on genetic, environmental and agronomic factors including growth regulation and the interaction between them. Here in these experiments growth regulating fungicides alter seed yield significantly at Giessen, while it was unaffected at RH. Results showed that TGW had positive relation with seed yield at both stations. Unapplied treatment exhibited lowest seed yield with minimum TGW at both stations. This yield loss was associated with the reduction of LAI. If the LAI is below the optimum that required to capture all of the light transmitted beyond the flower layer, then assimilate production will be reduced this would be expected to result in seed yield reduction. The maximum seed yield was recorded in case of combined application of Caramba and Cantus corresponding to the highest number of pods and seeds per main stem, contrary to that $Top_{0.5}$ in combination with Ortiva also attained higher yield but by improving LAI and TGW at Giessen. These results are coincided with the findings of Tuncturk and Ciftci (2007) who reported that number of seeds per pod, 1000-seed weight and number of seeds per pod have shown considerable direct positive effect on seed yield.

In these experiments seed yield was strongly related to the severity of lodging. Ortiva alone applied plants attained lowest seed yield which were susceptible to maximum lodging among fungicidal treatments at Giessen. Increases in individual seed weight in response to triazole included treatments were statistically negligible among each other although there was a trend for greater increases where the yield increases or lodging reduction was greatest. Previous studies found that yield improvements in response to triazole fungicides uniconazole and paclobutrazol were unrelated to changes in individual seed weight (Armstrong and Nicol 1991, Zhou and Ye 1996). A large LAI in case of $Top_{0.5}$ + Ortiva is likely result in more rapid stem elongation and the partitioning of a greater proportion of assimilate to above ground growth as a result of maximum seed yield at Giessen. It seems plausible that by reducing LAI and plant height resulting in a stronger stem. These effects may explain large reduction in lodging from combined application of Folicur and Proline at both stations.

Value of rapeseed linked to its seed oil content which was influenced significantly by application of fungicides at RH. At both stations it was observed that application of only triazole fungicides ($Top_{0.5}$ and Folicur + Proline) reduced oil content in comparison with control and other treatments. Similar oil content reducing effect was found by Setia et al. (1995) as well as Baylis and Hutley-Bull (1991) who used paclobutrazole in their experiments. Our results are contradicted with the investigations of Mert Türk et al. (2008) and Butkute et al. (2006) who worked with triazole fungicides Harvesan and Folicur respectively and reported that oil content of rapeseed increased significantly after their application in comparison with control. Application of Ortiva and Cantus in combination with triazole fungicides enhanced oil content by extending phase of seed formation which led increased oil accumulation in the seeds. Caramba included treatment which improved yield associated parameters (number of pods and seeds per main stem) and seed yield, also responsible to accumulate higher oil content.

In the literature it was explained that oil content of rapeseed was influenced by air temperature especially after flowering (Walton 1998). This was confirmed with our results in which oil content of seed samples from RH was 1% lower due to its higher air temperature (9.7 ^{o}C) than that of Giessen experimental station (8.5 ^{o}C). Hassan et al. 2007 also reported that increase of 1 ^{o}C temperature cause a loss of 1.2% of oil in the rapeseed. Interaction between fungicide and cultivar regarding oil content of rapeseed was observed significant at Giessen which showed that both cultivars respond in different way after application of fungicides regarding oil content.

Protein content in the seeds of rapeseed was influenced by fungicides at RH whereas in other experiment no clear variations were observed. Butkute et al. (2006) reported that application of Folicur on rapeseed enhanced protein content significantly than that of control. These results confirmed with our findings from RH. Among the fungicidal treatments, Ortiva application improved protein content significantly in comparison with the control at RH. Jenkyn et al. (2000) also reported that application of azoxystrobin enhanced protein content in the grains of wheat. An inverse relationship was observed between oil and protein in both experiments. Higher oil and lower protein content was accumulated in the seed samples of Giessen experimental station than that of RH experimental station may be due to temperature difference. These findings are consistent to those of Pritchard et al. (2000), who recorded increase of protein with decrease of oil content and concluded that wetter and cooler spring would favor higher oil accumulation, while lower proteins.

Significant interaction was recorded among cultivars and fungicides regarding oil and protein content at RH. Cultivars differed markedly for protein and oil content at both stations and showed different responses after application of fungicdes. Cv. NK Fair was late matured cultivar and its LAI was increased significantly at BBCH 80 than that of cv. Elektra. Due to its longer duration of seed filling may be favors higher oil and protein accumulation compared with cv. Elektra. These results are confirmed with the findings of Dimov and Möller (2010) that tested modern winter oilseed rape cultivars including cv. NK Fair and cv. Elektra in field experiments under typical German growing conditions.

In present study, concentration of free fatty acids (FFA) in the oil of rapeseed varied from 0.12 to 0.16% which was lower as reported by May et al. (1993) who obtained 0.41 to 0.54% FFA in the oil of rapeseed after application of fungicides. Experimental data demonstrated that concentration of FFA was significantly influenced by application of fungicides at RH, while FFA was unaffected at Giessen. May et al. (1993) reported that FFA was unaffected after application of fungicides, while FFA was significantly influenced by agronomic practices including low seeding rates, increased nitrogen fertilization and delayed planting in Ontario grown spring rapeseed. Concentration of FFA correlated with the intensity of lodging. Maximum FFA was recorded from heavily lodged Ortiva alone treated plants at both stations.

In this study, PV was altered significantly by application of fungicides at both stations. Growth regulator Moddus and triazole fungicides Folicur and Caramba included treatments reduced PV significantly than that of control treatment at both stations. This may be due to minimal damage of seeds during harvesting from these treatments. These treatments protected plants from severe lodging compared with control treatment. Lodging caused mechanical damage of seeds during harvesting (Baylis and Wright 1990). Damage seeds led to increase PV as reported by Appelqvist (1966). Severely lodged cv. Elektra also attained significantly higher PV compared with cv. NK Fair at RH.

Fatty acids profile (saturated and unsaturated) with the exception of major fatty acid oleic acid was altered significantly in the oil of rapeseed after application of fungicides. Significant lower concentration of palmitic acid was recorded by application of paclobutrazole containing fungicide Toprex at the rate of 0.35 L/ha than that of 0.5 L/ha at Giessen. These results were confirmed with the findings of Setia et al. (1996) who reported that by decreasing the dose of paclobutrazole, concentration of palmitic acid also reduced in the oil of *Brassica juncea* L. In this study, it is observed that fungicidal treatments like Caramba + Cantus which produced maximum oil content also attained higher oleic acid being a major component of rape oil which was confirmed with the findings of Mert Türk et al. (2008) who reported that application of triazole fungicide Harvesan increased oil content as well as oleic acid compared with unapplied treatment. Linoleic and linolenic acids were significantly affected by application of fungicides. These unsaturated fatty acids slightly increased their concentration by application of triazole fungicides $Top_{0.5}$ alone at Giessen and Folicur + Proline at RH among fungicidal treatments. Results demonstrated that increased oleic acid related to the decreased linoleic acid which also reported by Mekki et al. (2003) and Brar et al. (1998). This relation of fatty acids can be explained by the activity of the enzyme FAD2 which converts oleic acid to linoleic acid which is in turn converted to linolenic acid by FAD3 (Heinz 1993).

Summarizing all the results of this study, it is concluded that positive effects on plant growth like increased leaf area index and reduced plant height as expected when triazole and strobilurin fungicides are applied. The present study has shown that application of growth regulating fungicides is very effective to control overlarge canopies in order to reduce lodging and achieve an optimal sized seeds. Positive yield effects were achieved after combined application of triazole at BBCH 53 and strobilurin fungicides at BBCH 65 compared with their alone applications. Quality parameters of rape oil including oil content, fatty acid profile, free fatty acids and peroxide value somehow influenced by application of fungicides but these are also dependent from weather conditions and cultivar effects.

5.2 Fungicide and Fungicide × Sulphur Experiments

The application of fungicides had a variable effect on seed yield across the executed field experiments. However, a cross site analysis indicated that the combination of Ortiva (azoxystrobin) plus Toprex (paclobutrazole & difenoconazole) had a consistent positive effect on seed yield of rapeseed. This treatment achieved the enhancement of seed yield by minimizing lodging of the plants, while azoxystrobin promoted LAI and various seed yield components like TGW, number of pods per plant and number of seeds per plant. At the same time, its fungicidal action led to high degree of control over both Phoma and Sclerotinia. The use of either Cantus (boscalid) or Ortiva on their own had a positive effect on, respectively, plant height and LAI with consequent yield increased, but did not provide much disease control compared with alone applied treatments across all trials.

Both Caramba (metconazole) and Folicur (tebuconazole) application on its own reduced seed yield relative to the non-treated control. These treatments provided some disease control; thus their suppression of LAI and plant height presumably explained much of the seed yield reduction which they caused which contradicts with the findings of Berry and Spink (2009) who reported that spring alone application of Caramba increased seed yield of winter rapeseed significantly. Our findings are in agreement with the investigations of Pits et al. (2008) who observed yield reduction in case of Caramba application on rapeseed compared with control. Seed yield was significantly enhanced by the use of metconazole and tebuconazole in combination with azoxystrobin, which had positive effects on LAI and certain yield components associated with plant architecture, but were not so effective in providing disease control compared with their alone application.

Seed yield was responsive to the fungicidal treatments only in the field experiment RH 2009. In this experiment the combination of Moddus (trinexapac) with Cantus Gold (boscalid & dimoxystrobin) enhanced seed yield significantly by improving TGW and by reducing lodging of the plants. Application of Moddus on its own and in combination with Cantus Gold also enhanced morphological traits (pods/plant, seeds/pod and branches/plant) which are associated with seed yield of rapeseed. Alone application of Toprex reduced seed yield significantly due to its poor control against Sclerotinia relative to the combination with Ortiva at RH 2009. Negative seed yield effects were associated with more extensive lodging, earlier senescence, a larger canopy and greater disease severity.

The application of triazoles and strobilurins had a marked effect on LAI, due largely to a delay in leaf senescence and thus to the maintenance of a photosynthetically active area over a longer time of plant development. This result is in agreement with the observations of Zhou and Ye (1996), who found that triazole fungicides increased LAI of rapeseed significantly than that of untreated control. The application of the strobilurin azoxystrobin either on its own, or in combination with triazole fungicides enhanced LAI. The presence of tebuconazole on its own, or in combination with prothioconazole (Prosaro), however, reduced LAI, as also shown by Child et al. (1993). Triazole and strobilurin fungicides are known to affect the hormone balance in rapeseed leaves, with consequences for both GAI and plant height (Zhou et al. 1993). Strobilurins are thought to represent effective delayers of senescence, acting via a reduction in ethylene production (Wu and Tiedemann 2001). Lower ethylene concentrations slow the process of cytokinin degradation, which in turn delays senescence (Bollmark and Elisson 1990).

The application of Moddus (trinexapac) alone or in combination with a strobilurin fungicide had clear effect on lodging of the plants which was strongly reduced. This relation can be explained by the physiological action of this fungicide. Trinexapac is an antagonist of gibberellic acid, and can be used to improve root growth, stem strength (by reducing intercalary growth) and cell wall thickening (Pitann et al. 2010). Its primary action with respect to lodging in rapeseed is its suppression of plant height (Borovko 2008). Lodging occurring during flowering or early stage of pod development inevitably reduces seed set, because the lower layers of the canopy are no longer able to receive much light. Later lodging leads to harvest losses, as lodged plants cannot be easily combined. Finally, lodging can also reduce seed weight (Armstrong and Nicol 1991).

At both locations in 2009, incidence of Sclerotinia was not severe compared with Phoma. Higher infection rate of Phoma was detected in RH which is due to more precipitation in July (90.1mm). The relationship between weather conditions and disease infection is well known. Ghanbarnia et al. (2009) as well as Mendham et al. (1981) reported that rain fall and air temperature influenced the infection rate of Phoma in rapeseed. More lodging was observed from those plots, where incidence of *Phoma lingam* was more sever compared to others at both stations. Stem lesion girdle the stem base, prevent the flow of water up the stem and often result in lodging of the crop. Better control of diseases was achieved with twice application of fungicides which agrees with the finding of Balodis et al. (2008), Berry and Spink (2006).

Yield associated morphological traits were not influenced significantly by application of fungicides in these trials of Giessen 2009 and RH 2010. The application of Moddus (trinexapac) both alone and in combination with Cantus Gold (boscalid & dimoxystrobin) consistently increased seed size (TGW), as also noted by Borovko (2008) from summer rapeseed. Minimum TGW was recorded by application of metconazole alone as well as in combination with Azoxystrobin over other treatments including control which contradicts with the findings of Berry and Spink (2009) who reported that TGW of winter rapeseed was improved significantly by application of metconazole relative to untreated control. Maximum number of main branches with minimum plant height was recorded in case of Folicur included treatments at RH 2009. This suggested that assimilates were consumed for increasing morphological traits instead of plant height after application of Folicur. Number of pods per plant as well as seeds per pods was increased by application of Moddus on its own and in combination with Cantus Gold at both stations. Application of sulphur did not improve morphological traits significantly at RH 2010 which contradicts with the findings of Hassan et al. (2006) who reported that sulphur application increased seed yield as well as yield components (number of pods per plant, TGW and number of seeds per pod) significantly in comparison with no application of sulphur.

Applying Toprex (paclobutrazole & difenoconazole) at early flowering stage (BBCH 53) followed by treatment with azoxystrobin at the pod filling stage (BBCH 65) was effective for the accumulation of oil, for plant growth, and for several yield-associated morphological traits. It has been noted that paclobutrazole application to a *Brassica carinata* crop redirects assimilate towards the reproductive organs of the plant, thereby strengthening the assimilate sink (Setia et al.1995). The combination Moddus plus Cantus Gold (boscalid & dimoxystrobin) had a negative effect on oil content across the trials, unlike the finding reported by Borovko (2008), where trinexapac treatment had a positive effect on oil content who concluded that higher assimilate supply during grain filling was positively associated with high oil content.

The application of either Prosaro or Caramba at the pod filling stage was effective against lodging, for producing an optimal sized canopy, for encouraging seed oil content and for enhancing the production of assimilates and its translocation to the seeds. Supplementation with sulphur was ineffective in increasing either seed yield or seed oil content. It can be suggested that sulphur was not limiting factor for influencing seed yield and oil content of winter rapeseed during these experiments. The statistically non-significant differences for oil content due to sulphur application of present study are contrary to Jan et al. (2002), who recorded significant increase in oil content by sulphur application (60 kg S/ha) compared to control.

None of the treatments appeared to influence seed protein content, in contrast to what has been observed by Borovko (2008). Apart from significance application of Harvesan (flusilazole & carbendazim) and Prosaro increased protein content maximal compared other treatments across all trials, which is contrary with the effect of Harvesan reported by Mert-Türk et al. (2008) who found that application of Harvesan on winter rapeseed reduced protein accumulation significantly compared with unapplied. Supplementation with sulphur did, however, have a positive effect on both seed protein and glucosinolate content, as also shown by Hassan et al. (2006) and Jankowski et al. (2008). Sulphur plays an in dispensable role in rape plant as a component of protein and glucosinolates. Sulphur is reduced to cysteine and either converted to methionine or incorporated into protein and cysteine containing peptides such as glutathione. Hence sulphur is essential for protein formation, important for high protein content in rapeseeds as reported in our experiments. Wrigley et al. (1980) reported that under conditions of sulphur deficiency, composition of protein influenced with lower proportions of methionine and cysteine being present. Glucosinolates which are secondary metabolites containing β-thioglucose, a sulphonated oxime moiety and a side chain, their concentration is closely related to the sulphur supply because each glucosinolate molecule contains two or three sulphur atoms (Zhao et al. 1997).

Effect of fungicide application on quality parameters of rapeseed oil was not so prominent in both growing seasons. Free fatty acid values in both growing years ranging from 0.1 to 2% with a mean of 0.3 % which coincide the findings of Daun et al. (1985). However, value of FFA (unesterified fatty acids) was significantly affected by fungicidal treatments in RH in both years while no significant variation was observed in GI. Untreated plots reduced the value of FFA in comparison with fungicidal treatments in both years. Highest values of FFA were reported from the samples of GI because at maturity time and near to harvesting crop subjected to heavy rain fall. Environmental conditions also appear to predispose the seed to higher level of free fatty acids. However, the FFA levels may be elevated in seed that was subjected to wet harvesting conditions (July rain fall), mechanical damage of seeds, drying temperature and improper storage conditions (Savic et al. 2009, Pathak et al. 1991). The PV value provides an indicator of the presence of primary oxidation products in the oil. Such compounds arise from the oxidation of polyunsaturated fatty acids. PV tends to rise with oil storage time, temperature, exposure to trace amounts of heavy metal and contact with air (Siddique et al. 2010). The fungicide treatments had a marked effect on PV in all but the GI 2009 experiment. The application of Caramba either on its own and in combination with Ortiva, increased oil rancidity (as measured by a rise in PV). A cross site analysis confirmed that the use of Moddus on its own reduced PV. Environmental factors can also account for variation in seed yield, seed oil and protein content, and the FFA, PV and fatty acid composition of the oil. PV was overall larger in the rain-affected GI 2009 material than in the more normal RH 2010 harvest.

Oleic acid is the major fatty acid of rapeseed which was not affected significantly in both growing seasons with application of fungicides. This result is in agreement with previously reported findings of Mert-Türk et al. (2008). It was observed from executed experiments, an increased oleic acid was related to decrease in linoleic acid content which relates the results of Mekki (2003) as well as Brar et al. (1998). Effect of fungicides on the concentration of linoleic acid was statistically significant in all experiments except in GI 2009. Mert-Türk et al. (2008) and Zhou and Ye (1996) reported that fungicide application had non-significant effects on fatty acid composition in the oil of rapeseed. Setia et al. (1996) investigated that linoleic and linolenic acid concentration in the oil of *Brassica juncea* were slightly altered with triazole treatments which coincide our findings. Moddus alone and Folicur + Ortiva applications enhanced the concentration of oil as well as linoleic and linolenic acid. These results are agreed with the findings of Borovko (2008). Concentration of palmitic acid was affected significantly with application of fungicides in all performed experiments. Cantus application improved the quality of rapeseed oil by reducing palmitic acid significantly by other treatments in 2009 at both stations. These significant effects of fungicides on the concentration of fatty acids may be due to improving the enzymatic activities which also concluded by Zhou and Leul (1998), Setia et al. (1996), Zhou and Ye (1996) and Zhou and Xi (1993b)

The overall conclusion is that the combined treatment of Toprex (paclobutrazole & difenoconazole) and Ortiva (azoxystrobin) had a positive effect on the productivity of rapeseed, through its induction of a more upright canopy, which is less susceptible to disease and lodging, and which allows for a better level of light penetration.

5.3 Fungicide × Nitrogen Experiments

Results of the executed field experiments revealed that application timings of fungicides contributed to alter leaf area index (LAI). So it could be found that autumn and spring alone applied treatments (Caramba, Folicur and Moddus) increased LAI in spring but reduced it after BBCH 70 and reached near to minimal LAI like unapplied control at BBCH 80 in both seasons. Triazole fungicides were applied in autumn to improve cold hardiness and the winter survival of rapeseed (Morison and Andrews 1992). The physiological background of this effect can be explained by increased number of palisade and mesophyll layers in the leaves of rapeseed. Inhibition of gibberellins by triazole may make more substrate available for the synthesis of abscisic acid (ABA) and cytokinins. ABA may strengthen the microtubular network associated with membranes as well as increase the intracellular concentration of cryoprotective proteins (Flores et al. 1988). All these investigations were confirmed with results of our experiments. The present study confirmed that LAI was reduced by alone application of Folicur (tebuconazole) at BBCH 53 compared with other fungicidal treatments including control in all experiments. Combined application of Folicur with Cantus Gold (boscalid & dimoxystrobin) enhanced LAI in comparison with its alone application. Autumn applied treatments attained maximum LAI in spring season. Inclusion of strobilurin fungicide in spring applied treatments improved LAI by delaying senescence after BBCH 70. Combination of Cantus Gold with growth regulator Moddus (trinexapac) was considered best to enhance LAI among Cantus Gold included treatments. It can be supposed that application of strobilurin fungicide Ortiva (azoxystrobin) on already triazole treated plants prolonged the photosynthetic duration of green tissues by reducing ethylene production (Grossmann et al. 1999) as well as increased nitrate assimilation rate by enhancing the activity of nitrate reductase (Köehle et al. 2003) consequently increased LAI at the later stages of rapeseed. Same results were reported by Ruske et al. (2003) who carried out experiments with winter wheat. As nitrogen is an integral part of chlorophyll hence increase of nitrogen level revealed maximum LAI compared with lower level of nitrogen (Wright et al. 1988).

Plant height was significantly altered by application of antigibberellin triazole fungicides and growth regulator Moddus (trinexapac) alone as well as in combination with strobilurin. Short statured plants of winter rapeseed were obtained in case of spring alone application of Folicur and Caramba (metconazole) over other treatments. These results are in agreement with the investigations of Berry and Spink (2009) as well as Child et al. (1993) who reported that application of Caramba and Folicur reduced plant height of winter rapeseed significantly than that control. Combination of Caramba with Moddus and Cantus Gold also responsible to reduce plant height prominently than that of autumn applied and control treatments. Autumn applied treatments had small influence on the reduction of plant height and reached statistically similar values like control in all experiments. It can be concluded that autumn application of growth regulators is no suitable way to control lodging of winter rapeseed. Maximum reduction in plant height was observed when fungicides were applied at BBCH 53 alone as well as in combination. At this stage stem shooting of rape plant is very quick and application of antigibberellin products slow down this process compared with other treatments (Scarisbrick et al. 1985). Same response of Folicur and Caramba application at autumn and spring on plant height of winter rapeseed was also recorded by Dapprich et al. (2002). More reduction in plant height was recorded in case of spring alone application compared with its combination with strobilurin fungicides at both locations. Higher level of nitrogen did not increase plant height significantly at GI in both years which contradict with the findings of Öztürk 2010. Plant height was influenced significantly by higher level of nitrogen at RH 2010. In both years plant height at RH was higher than that of GI due to different environmental and soil conditions of both experimental stations.

Seed yield did not alter significantly by application of triazole and strobilurin fungicides in all executed experiments. These results do not support the findings of Berry and Spink (2009) who reported that triazole application enhanced seed yield of winter rapeseed significantly by improving green area index and yield attributed traits. Apart from significance Cantus Gold + Moddus included treatments led to maximum seed yield in both seasons at Giessen. These treatments attained higher LAI as well as prolonged green leaf area retention which has been suggested to be the main factor for yield increase, because increased photosynthetic duration would enhance the quantity of assimilate availability for grain filling. Fungicidal treatments did not show any clear and continues effect on seed yield at RH in both years. As LAI is an important structural property of crop canopy which predicts photosynthesis and which can be characterized as a reference tool for crop growth measurements (Lan et al. 2009). Autumn applied and control treatments reduced LAI to its minimal level after BBCH 70 consequently exhibited minimal seed yield over other treatments at both stations for all experiments. Morphological parameters which were associated with seed yield of rapeseed also unaffected by application of fungicides in all experiments. These results contradicted with the findings of Zhou and Ye (1996) and supported by Scarisbrick et al. (1985). Alone application of Folicur in autumn and spring had negative impact on morphological traits of winter rapeseed during both seasons. Carax (metconazole/mepiquat chloride) in combination with Proline (prothioconazole) treated plants attained maximum number of pods and branches per plant at RH 2010. Number of pods per plant had inverse relation with the number of seeds per pod and pod length during these experiments. Higher level of nitrogen did not improve seed yield significantly at Giessen, while it was significantly increased than that of lower level of nitrogen by improving morphological parameter of rapeseed (Yasari and Patwardan 2006) at RH during both growing years.

Rapeseed plant which is more vulnerable to lodging was protected more efficiently by applying fungicides and growth regulator compared with unapplied control in these experiments. Shorter plants with stronger stems produced by spring alone application of Caramba and Folicur which resistant to lodging. These shorter plants combination with the more even and compact pod canopy reduced pod shattering during maturation. This means that direct harvesting in commercial operation could become plausible, particularly when combined with uniform ripening. Among fungicidal treatments autumn application which had no influence in the reduction of plant height and were more susceptible to lodging like control in all experiments. In rapeseed lodging has also been shown to increase the number of seeds lost at harvest (Armstrong and Nicol, 1991). Baylis and Hutley-Bull (1991) reported that lodging would also be expected to reduce the individual weight of grain. This has been confirmed in our experiments with Moddus included treatments which improved TGW by giving best control against lodging over other treatments. Lodging control has been shown to be strongly determined by the degree of height reduction achieved by Moddus. In 2010 maximum value of TGW was recorded in case of spring applied Folicur which produced short statured plants. These results are coincided with the findings of Dapprich et al. (2002). Higher level of nitrogen did not enhance the incidence of lodging prominently in all experiments.

Seed yield was related to the incidence of diseases which was more clear in 2010 when seed yield was reduced half than previous year due to increase in disease attack at RH. Incidence of Sclerotinia was so severe in 2010 due to higher precipitation rate in the month of June near to maturity in comparison with 2009. At RH in 2010 maximum seed yield was recorded by application of Toprex + Ortiva application due to its best control against diseases over other treatments. Minimum incidence of diseases was recorded by combined application of triazole and strobilurin group of fungicides which have different mode of actions against pathogen in comparison with alone applied triazole fungicides and growth regulator. Among alone applied treatments autumn application did not have any control against diseases like untreated control in all experiments. There was no prominent difference in the severity of diseases among nitrogen levels in all experiments.

Oil content was significantly influenced by application of fungicides in all experiments with the exception of Giessen 2009. In 2010 at both stations Carax included treatments increased oil content significantly than that of control and single applied treatments with the exception of autumn applied Moddus at Giessen. Conversely, autumn and spring alone applied Folicur and Caramba improved oil content significantly in RH 2009. Similar results were observed in summer rapeseed by Borovko (2008) who reported that application of Folicur improved oil content significantly. Significant increase in oil content was investigated by Zhou and Ye (1996) and Setia et al. (1996) after applying uniconazole and paclobutrazole on *Brassica napus* and *Brassica juncea* respectively. Oil makes up about 29-54% of the dry weight of *Brassica* seeds (Sing and Mehta 1992) and its synthesis from sucrose constitute one of the major metabolic activities of the embryo during seed development (Perry and Harwood 1993). Oil filling in the seeds of rapeseed coincided with the decrease in starch and total soluble sugar content in the seeds. Application of Paclobutrazole enhanced the activity of α and ß-amylase enzymes in the pods which suggest that starch degradation furnished precursors for the biosynthesis of storage lipids in the seeds (Setia et al. 1996).

Apart from RH 2010 there was a significant interaction between fungicides and nitrogen regarding oil content in all other experiments. In all experiments higher level of nitrogen reduced oil content in the seeds of rape. More nitrogen increased protein content in the seeds of rapeseed, as a result there was decrease in the percentage of oil content since it has inverse relationship with protein. The results agree with those documented by Jan et al. (2002).

The glucosinolate is a large group of sulphur-containing secondary plant metabolites. Glucosinolate content limits efficient utilization of rape meal. Spring application of Moddus on its own as well as in combination with Caramba and Cantus Gold improved rape meal quality by reducing glucosinolates content than other treatments in all experiments. There was not a consistent variation in the glucosinolate content of other fungicidal treatments during these experiments. It was observed that glucosinolate content was inversely related with oil content and directly related with protein content (Mert-Türk et al. 2008)). In 2009 seeds of rapeseed attained more oil content with lower glucosinolates and protein content than that of 2010 in all experiments. Baylis and Hutley-Bull (1991) reported that paclobutrazole reduced glucosinolates in the seeds of rapeseed significantly than that of control which is not supported with our findings. Increasing the nitrogen rate enhanced the relative proportion of alkenyl glucosinolates by favoring the hydroxylation step from but-enyl to 2-hydroxybut-3-enyl (Zhao et al. 1994). Some contradicted data can be found. Zukalova et al. (2001) reported that increased nitrogen fertilization tends to reduce glucosinolates content, and this is explained by the fact that higher nitrogen slow down the uptake of sulphur from the soil.

Rapeseed meal is an excellent source of protein for animals (Friedmann 1996). Protein content of rapeseed grains in own experiments was significantly influenced by the application of fungicides only in one experiment (RH 2010). In this experiment spring application of Folicur in combination with Cantus Gold significantly increased protein content which was higher than in Moddus included treatments. These results are contradicted with the findings of Matysiak (2006) who reported that protein content was increased in wheat after application of Moddus. This is may be due to increasing nitrogen use efficiency in response of more biomass of roots after application of Moddus as reported by Pittan et al (2010). Degree of disease severity also contributed on quality parameters of rapeseed. Higher protein content with lower oil content was recorded in 2010 due to severe disease attack compared with 2009 at both sites. These results are supported by McCartney et al. (1999). Higher level of nitrogen increased protein content as it is integral part of major amino acids histidine and threonine (Brennan et al. 2000).

Free fatty acids indicate the extent of lipolysis in the oil of rapeseed. Hydrolysis takes place at the junction of the fatty acids and the glycerol portion of the triglyceride, resulting in glycerol and free fatty acids (Belitz and Grosch 1999). Concentration of free fatty acids (FFA) was significantly affected by fungicidal treatments at RH in both years and in Giessen 2010. Apart from statistical significance autumn applied Caramba led to lowest concentration of FFA in 2009 at both stations and in 2010 at RH. During these experiments it was observed that autumn applied treatments induced lower FFA in the oil of rapeseed. Fungicidal treatments did not show consistent changes in FFA in these experiments which were coincided with the findings of May et al. (1993). Factors which lead to a high FFA in rape oil include delays between harvesting and extraction (especially if the seeds has been bruised or damaged during harvesting), fungal diseases (McCartney et al. 1999), prolonged contact between oil and vegetation water (after extraction), and careless extraction methods. FFA was significantly increased by applying higher level of nitrogen in all experiments. These results are supported by May et al. (1993).

Peroxides value (PV) which is an indication of the amount of hydroperoxides and arises from oxidation of polyunsaturated fatty acids of rapeseed was significantly altered by application of fungicides in 2009 at RH and 2010 at Giessen, while it was not influenced statistically in other experiments. It can be supposed that the growing and weather conditions of the plant modified these effects because in 2009 maximum PV was recorded due to rainy weather at maturity time over 2010. Similar finding was published by Becker et al. (1999) who reported that environmental conditions also accounted for variation in PV of rapeseed oil. There was not a consistent effect of fungicides on PV in these experiments. Interaction between fungicides and nitrogen was significant in all experiments for PV. In 2010 at both stations higher level of nitrogen significantly decreased PV, while it was enhanced in 2009 in comparison with lower level of nitrogen at both stations.

Composition of fatty acids in the oil of rapeseed is highly genetically determined (cultivar specific). Additionally weather conditions can modify fatty acid composition

(Baux et al. 2008). Interestingly, concentration of oleic and linolenic acid in the oil of rapeseed was altered significantly by application of fungicides in 2010 in both stations and in 2009 only in RH. These results are supported by Setia et al. (1996) who reported from *Brassica juncea* with triazole fungicide, while contradicted with the findings of Zhou and Ye (1996) as well as Mert-Türk et al. (2008). Toprex + Proline treatment exhibited lowest value of oleic acid than that of other treatments in 2009 at both stations. It was observed in 2010 at RH Carax included treatments which accumulated maximum oil also responsible to attain maximum concentration of oleic acid. Application of fungicides significantly affected linoleic acid in all experiments. Apart from significance maximum concentration of linoleic acid was recorded from spring alone applied Moddus in 2010 at both stations and in 2009 at Giessen. The negative relationship between oleic and both polyunsaturated fatty acids established. This consistent previous data from Kotechi et al. (2002), who reported that the increase of linoleic and linolenic acid occur in the years unfavorable to oleic acid accumulation. Higher level of nitrogen increased oleic acid and decreased concentration of linoleic acid in all experiments. Same results were reported by Karaaslan and Özgüven (2001). Linolenic acid was increased in 2009 and decreased in 2010 with higher level of nitrogen at both stations. Results of Baux et al. 2011 also showed that an increase in nitrogen supply can significantly increase linolenic acid and decrease oleic acid content.

In conclusion, combined application of fungicides (triazole and strobilurin) with interaction of nitrogen appeared to delay senescence, avoid lodging and improve quality components of winter rapeseed. Spring application of fungicides showed reduction in plant height and lower degree of lodging, with occasional improvements in seed quality. The increase in nitrogen content leads to enhance protein content and decrease in the oil content of the seed. The information helps to understand the other role of fungicides except for the control of plant diseases and provides insight how combined and alone spring application improve key aspects of growth, yield and quality.

6. SUMMARY

Field experiments with rapeseed (*Brassica napus* L.) were carried out from 2007 to 2010 to clarify the effects of triazole and strobilurin fungicides on seed yield and its components as well as on grain quality of the crop under different growing conditions.

The field experiments were conducted at the experimental stations in Giessen (silt clay soil) and Rauischholzhausen (loess soil). Three types of field experiments were carried out: 1. fungicides/growth regulator in combination with two cultivars (two experiments), 2. fungicides in combination with nitrogen (four experiments) and 3. sulphur fertilization in combination with fungicides (three experiments). The used triazole and strobilurin fungicides and the trinexapac growth regulator were applied in different combinations at three different growth stages of winter rapeseed. Morphological and physiological data including seeds/pod, pods/plant, pod length, primary and secondary branches per plant, plant height and leaf area index (LAI) were collected. Incidence of diseases and lodging was assessed. Oil content, fatty acid profile, protein content, content of glucosinolates and free fatty acids as well as peroxide values were analyzed as quality parameters. All collected data were statistically analyzed by statistical package PIAF.

Results of the experiments revealed that combined application of triazoles and strobilurins had a marked effect on LAI, largely due to a delay in leaf senescence and thus owing to maintenance of a photosynthetically active area over a longer time. Timings of fungicides had clear effect on plant height and LAI of the plant stand. Plant height was reduced significantly by application of fungicides at BBCH 53 compared with autumn application. Growth regulator Moddus (trinexapac) alone as well as in combination with fungicides increased TGW and improved stem stability by reducing intercalary growth. Morphological parameters (seeds/pod, pods/plant, pod length and primary and secondary branches per plant) of rapeseed were not affected by application of fungicides in all experiments. Combined application of Toprex (paclobutrazole & difenoconazole) and Ortiva (azoxystrobin) increased seed yield due to higher LAI and effectively control of diseases. Caramba (metconazole) and Folicur (tebuconazole) application on its own reduced seed yield relative to their combinations with Ortiva. These triazole fungicides provided disease control to some extent, but suppression of LAI and plant height presumably explained much of the seed yield reduction which they caused.

Within seed quality parameters of rapeseed, oil content was enhanced by application of Ortiva in combination with other triazole fungicides by prolonging duration for seed filling. The increase of nitrogen fertilization enhanced protein content and decreased the oil content of the seeds. Significant interaction between fungicides and nitrogen was found regarding oil content. Carax (metconazole & mepiqua chloride) included treatments in combination with lower level of nitrogen increased oil content in comparison with other treatments. Fungicides did not alter protein content significantly in most field experiments. Cultivar NK Fair exhibited significantly higher oil, protein and oleic acid contents in comparison with cv. Elektra. Sulphur application enhanced protein percentage but had no effect on oil content. Application of Moddus at BBCH 53 alone as well as in combination with fungicides somehow reduced glucosinolates in all experiments. Fungicides did not exceed the values of free fatty acids and peroxides at such hazardous limits. Wet weather conditions and severe lodging near to maturity also contributed to influence free fatty acids and peroxides in the oil of rapeseed. The proportion of oleic acid was unaffected, while polyunsaturated fatty acids (linoleic and linolenic acid) were affected significantly by the application of fungicides in most experiments. Oleic acid showed a positive correlation with oil content and it was negatively correlated with polyunsaturated fatty acids.

Generally it can be concluded that application of triazole and strobilurin fungicides may have various effects on winter rapeseed physiology by increasing leaf area index and modifying the optimal upright canopy. Plants which are applied with these fungicides are less susceptible to lodging, and characterized by delayed leaf senescence which promoted the light interception of plant stand. Triazole and strobilurin fungicide combinations have the potential to improve several growth parameters which limit the yield of winter rapeseed. The use of fungicides prevented a considerable loss in yield, but had no deleterious effect on oil quality.

7. ZUSAMMENFASSUNG

In der Zeit von 2007 bis 2010 wurden mehrere Feldversuche mit Winterraps (*Brassica napus* L.) durchgeführt, um den Einfluss von Triazol- und Strobilurin-Fungiziden auf den Samenertrag und die Ertragskomponenten sowie auf die Qualität der Samen unter unterschiedlichen Wachstumsbedingungen zu klären.

Die Feldversuche wurden in den Versuchsstationen Gießen (schluffiger Tonboden) und Rauischholzhausen (Lössboden) mit drei Fragestellungen durchgeführt: 1. Fungizid/Wachstumsregulator in Kombination mit zwei Sorten (zwei Versuche); 2. Fungizide in Kombination mit Stickstoff (vier Versuche) und 3. Schwefeldüngung in Kombination mit Fungiziden (drei Versuche). Die verwendeten Triazol- und Strobilurin-Fungizide sowie der Wachstumsregulator Trinexapac wurden in unterschiedlichen Kombinationen zu jeweils drei verschiedenen Wachstumsstadien des Winterrapses appliziert. Es wurden Daten zu morphologischen und physiologischen Parametern erhoben, darunter Samen/Schote, Schoten/Pflanze, Schotenlänge sowie die Anzahl der primären und sekundären Seitentriebe pro Pflanze, die Pflanzenhöhe und der Blattflächenindex. Darüber hinaus wurden das Auftreten von Krankheiten und Lager evaluiert und die Qualitätsparameter Ölgehalt, Fettsäureprofil, Proteingehalt, Glucosinolatgehalt, der Gehalt an freien Fettsäuren und die Peroxidzahl gemessen. Sämtliche erhobenen Daten wurden mit dem Statistikprogramm PIAF ausgewertet.

Die gewonnenen Ergebnisse zeigten, dass eine kombinierte Anwendung von Triazolen und Strobilurinen einen deutlichen Einfluss auf den Blattflächen-Index hat. Dieser Einfluss ist im Wesentlichen auf eine verzögerte Blattseneszenz und somit auf die damit einhergehende Aufrechterhaltung verlängerte Photosynthese-Aktivität der Pflanzen zurückzuführen. Der Zeitpunkt der Fungizidapplikation hatte einen signifikanten Einfluss auf die Pflanzenhöhe und den Blattflächenindex des Pflanzenbestandes. Die Pflanzenhöhe wurde durch die Fungizidapplikation im Stadium BBCH 53, im Vergleich zur Herbstapplikation, signifikant reduziert. Der Wachstumsregulator Moddus (Trinexapac) reduzierte sowohl einzeln als auch in Kombination mit den Fungiziden das interkalare Wachstum der Halme und verbesserte damit die Standfestigkeit sowie das TKG der Pflanzen. Morphologische Merkmale des Rapses wurden durch die Applikation der Fungizide in keinem der Versuche beeinflusst. Die kombinierte Anwendung von Toprex (Paclobutrazol & Difenoconazol) und Ortiva (Azoxystrobin) erhöhte den Samenertrag aufgrund des verbesserten Blattflächenindexes und der geringeren Krankheitsanfälligkeit. Die Anwendung von Caramba (Metconazol) und Folicur (Tebuconazol) allein reduzierte den Samenertrag im Vergleich zu deren Kombination mit Ortiva. Diese Triazolfungizide führten zwar zu einer Verminderung der Krankheiten, reduzierten jedoch den Samenertrag, was vermutlich auf einen niedrigeren Blattflächenindex und eine geringere Anlage von ertragsrelevanten Organen der Pflanze zurückzuführen ist.

Die Anwendung von Ortiva hatte in Verbindung mit anderen Triazolfungiziden eine Erhöhung des Ölgehaltes aufgrund der längeren Kornfüllungsphase zur Folge. Die Erhöhung der Stickstoffdüngung führte erwartungsgemäß zu einem höheren Proteingehalt und zu einem geringeren Ölgehalt der Samen. In den durchgeführten Versuchen wurde eine signifikante Wechselwirkung zwischen Fungiziden und Stickstoff-Düngung festgestellt. In den meisten Feldversuchen wurde der Proteingehalt durch die Fungizidapplikation nicht signifikant verändert. Im Vergleich mit Elektra wies die Sorte NK Fair signifikant höhere Gehalte an Öl, Protein und Ölsäure auf. Schwefeldüngung erhöhte den Proteingehalt, hatte jedoch keinen Einfluss auf den Ölgehalt in den Samen. Die Applikation von Moddus bei BBCH 53, einzeln und in Kombination, reduzierte den Gehalt an Glucosinolaten in allen durchgeführten Versuchen. Die Gehalte an freien Fettsäuren und Peroxiden im Öl wurden vor allem durch die feuchte Witterung und durch das Lagern der Rapspflanzen erhöht. Der Anteil an Ölsäure blieb zumeist unverändert, während der Anteil an mehrfach ungesättigten Fettsäuren in den meisten Versuchen beeinflusst wurde. Der Ölsäuregehalt korrelierte positiv mit dem Ölgehalt, während sich eine negative Korrelation mit mehrfach ungesättigten Fettsäuren zeigte.

Aus den Ergebnissen lässt sich schließen, dass die physiologische Wirksamkeit von Triazol- und Strobilurin-Fungiziden zum Teil auch unter Feldbedingungen nachgewiesen werden kann. Pflanzen, die mit diesen Fungiziden behandelt wurden, zeigten generell eine geringere Lagerneigung und eine verzögerte Blattseneszenz, wodurch die Lichtinterzeption im Pflanzenbestand verbessert wird. Die kombinierte Anwendung von Triazol- und Strobilurin-Fungiziden kann somit zahlreiche Wachstumsparameter verbessern, die für die Ertragsbildung des Winterrapses von Bedeutung sind.

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9. APPENDICES

Appendix 1: Production (tones), area (hectares) and seed yield (tones/ha) of the world's top rapeseed producing countries (FAO Stat 2010)

Country	Production (tones)	Area (ha)	Seed yield (tones/ha)
China	13082010	7370010	1.78
Canada	11866200	6514400	1.82
India	6410000	5530000	1.16
Germany	5697600	1461200	3.90
France	4815520	1465230	3.29
United Kingdom	2230000	653000	3.42
Australia	2180600	1729100	1.26
Poland	2077630	769331	2.70
Europe	23074394	87877770	2.63
World	**59067597**	**31680945**	**1.87**

Appendix 2: Trade name, active ingredient and concentration of tested fungicides and growth regulator

Trade name	Active ingredient	Concentration
	Triazoles	
Proline [1)]	Prothioconazole	250 g/L
Folicur [1)]	Tebuconazole	251.2 g/L
Prosaro [1)]	Prothioconazole	125 g/L
	Tebuconazole	125 g/L
Caramba [2)]	Metconazole	60 g/L
Carax [2)]	Metconazole	30 g/L
	Mepiqua Chloride	210 g/L
Harvesan [3)]	Flusilazole	250 g/L
	Carbendazim	125 g/L
Toprex [4)]	Difenoconazole	250 g/L
	Paclobutrazol	125 g/L
	Strobilurins	
Ortiva [4)]	Azoxystrobin	250 g/L
Cantus Gold [2)]	Boscalid	200 g/L
	Dimoxystibin	200 g/L
Cantus [2)5)]	Boscalid	500 g/L
	Growth regulator	
Moddus [4)]	Trinexapac	222 g/L
	Ethylester	250 g/L

[1)] Bayer Crop Science [2)] BASF [3)] Dupont [4)] Syngenta, [5)] Cantus is not a strobilurin fungicide but has same mode of action

Appendix 3: ANOVA p values for main effects and interaction between fungicides and cultivars of LAI, seed yield, TGW, plant height, oil content, protein content, free fatty acids, peroxides value and unsaturated fatty acids at Giessen and Rauischholzhausen 2008

Study parameters	**Giessen**			**Rauischholzhausen**		
	Fun.	**CV**	**Fun. x CV**	**Fun.**	**CV**	**Fun. x CV**
LAI (BBCH 62)	0.341	0.404	0.876	-	-	-
LAI (BBCH 70)	0.556	0.522	0.999	-	-	-
LAI (BBCH 75)	0.448	0.948	0.989	-	-	-
LAI (BBCH 80)	0.000	0.006	0.378	-	-	-
Seed yield (dt/ha)	0.000	0.942	0.130	0.001	0.000	0.604
TGW (g)	0.013	0.000	0.932	0.057	0.000	0.052
Plant height (cm)	0.006	0.000	0.010	0.002	0.000	0.705
Oil content (%)	0.447	0.000	0.550	0.030	0.000	0.001
Protein content (%)	0.000	0.858	0.937	0.002	0.000	0.001
Free fatty acids (%)	0.214	0.583	0.007	0.047	0.001	0.014
Peroxides value (mequ/kg)	0.000	0.000	0.000	0.000	0.000	0.063
Oleic acid (%)	0.567	0.000	0.102	0.188	0.192	0.567
Linoleic acid (%)	0.006	0.000	0.070	0.000	0.070	0.000
Linolenic acid (%)	0.048	0.000	0.797	0.000	0.096	0.000

Fun = Fungicides, CV = Cultivars, LAI = Leaf area index, TGW = 1000-grain weight

Appendix 4: ANOVA p values for effects of fungicides of LAI, seed yield, TGW, plant height, oil content, protein content, free fatty acids, Peroxides value and unsaturated fatty acids at Giessen and Rauischholzhausen 2009

Study parameters	**Giessen**	**Rauischholzhausen**
LAI (BBCH 68)	0.041	-
LAI (BBCH 76)	0.108	-
LAI (BBCH 80)	0.148	-
Seed yield (dt/ha)	0.902	0.017
TGW (g)	0.032	0.299
Plant height (cm)	0.099	0.023
Oil content (%)	0.038	0.043
Protein content (%)	0.479	0.479
Free fatty acids (%)	0.389	0.000
Peroxides value (mequ/kg)	0.053	0.000
Oleic acid (%)	0.156	0.120
Linoleic acid (%)	0.089	0.000
Linolenic acid (%)	0.324	0.000

LAI = Leaf area index, TGW = 1000-grain weight

Appendix 5: ANOVA p values for main effects and interaction between fungicides and sulphur of LAI, seed yield, TGW, plant height, oil content, protein content, free fatty acids, Peroxides value and unsaturated fatty acids at Rauischholzhausen 2010

Study parameters	Fungicide	Sulphur	Fungicide x Sulphur
LAI (BBCH (60)	0.031	0.402	0.827
LAI (BBCH (70)	0.763	0.002	0.764
LAI (BBCH (78)	0.000	0.000	0.000
Seed yield (dt/ha)	0.074	0.121	0.775
TGW (g)	0.210	0.910	0.985
Plant height (cm)	0.003	0.003	0.976
Oil content (%)	0.990	0.001	0.006
Protein content (%)	0.607	0.000	0.146
Glucosinolates (mmol/g)	0.141	0.000	0.213
Free fatty acids (%)	0.010	0.014	0.460
Peroxides value (mequ/kg)	0.000	0.000	0.000
Oleic acid (%)	0.239	0.006	0.503
Linoleic acid (%)	0.000	0.000	0.826
Linolenic acid (%)	0.058	0.003	0.233

LAI = Leaf area index, TGW = 1000-grain weight

Appendix 6: ANOVA p values for main effects and interaction between fungicides and nitrogen of seed yield, TGW, plant height, oil content, protein content, free fatty acids, Peroxides value and unsaturated fatty acids at Giessen and Rauischholzhausen 2009

Study parameters	Giessen			Rauischholzhausen		
	Fun.	N	Fun. x N	Fun.	N	Fun. x N
LAI (BBCH 58)	0.003	0.000	0.636	-	-	-
LAI (BBCH 68)	0.013	0.000	0.532	-	-	-
LAI (BBCH 84)	0.001	0.000	0.056	-	-	-
Seed yield (dt/ha)	0.149	0.185	0.423	0.708	0.000	0.761
TGW (g)	0.148	0.698	0.320	0.174	0.083	0.255
Plant height (cm)	0.034	0.000	0.532	0.000	0.271	0.812
Oil content (%)	0.246	0.117	0.007	0.000	0.530	0.008
Protein content (%)	0.126	0.000	0.484	0.284	0.000	0.897
Glucosinolates (mmol/g)	0.323	0.003	0.043	0.002	0.000	0.040
Free fatty acids (%)	0.092	0.176	0.626	0.034	0.120	0.842
Peroxides value (mequ/kg)	0.243	0.012	0.492	0.034	0.001	0.194
Oleic acid (%)	0.693	0.003	0.0341	0.000	0.000	0.000
Linoleic acid (%)	0.017	0.000	0.003	0.000	0.000	0.000
Linolenic acid (%)	0.539	0.003	0.004	0.000	0.020	0.569

Fun = Fungicides, N = Nitrogen, LAI = Leaf area index, TGW = 1000-grain weight

Appendix 7: ANOVA p values for main effects and interaction between fungicides and nitrogen of LAI, seed yield, TGW, plant height, oil content, protein content, free fatty acids, Peroxides value and unsaturated fatty acids at Giessen and Rauischholzhausen 2010

Study parameters	**Giessen**			**Rauischholzhausen**		
	Fun.	**N**	**Fun. x N**	**Fun.**	**N**	**Fun. x N**
LAI (BBCH 60)	0.062	0.025	0.256	0.019	0.001	0.833
LAI (BBCH 70)	0.112	0.001	0.881	0.016	0.001	0.871
LAI (BBCH 78/80)	0.002	0.109	0.985	0.001	0.000	0.171
Seed yield (dt/ha)	0.378	0.169	0.718	0.159	0.001	0.106
TGW (g)	0.002	0.000	0.080	0.008	0.108	0.945
Plant height (cm)	0.000	0.214	0.206	0.000	0.006	0.957
Oil content (%)	0.000	0.000	0.032	0.000	0.000	0.956
Protein content (%)	0.768	0.000	0.536	0.009	0.000	0.467
Glucosinolates (mmol/g)	0.000	0.004	0.463	0.087	0.000	0.561
Free fatty acids (%)	0.011	0.003	0.166	0.011	0.000	0.280
Peroxides value (mequ/kg)	0.000	0.020	0.003	0.157	0.000	0.000
Oleic acid (%)	0.013	0.454	0.655	0.001	0.000	0.005
Linoleic acid (%)	0.000	0.000	0.630	0.000	0.001	0.365
Linolenic acid (%)	0.000	0.000	0.719	0.000	0.000	0.000

Fun = Fungicides, N = Nitrogen, LAI = Leaf area index, TGW = 1000-grain weight

DECLARATION / ERKLÄRUNG

I declare: this dissertation submitted is a work of my own, written without any illegitimate help by any third party and only with materials indicated in the dissertation. I have indicated in the text where I have used texts from already published sources, either word for word or in substance, and where I have made statements based on oral information given to me. At any time during the investigations carried out by me and described in the dissertation, I followed the principles of good scientific practice as defined in the "Statutes of the Justus Liebig University Giessen for the Safeguarding of Good Scientific Practice".

„Ich erkläre: Ich habe die vorgelegte Dissertation selbständig und ohne unerlaubte fremde Hilfe und nur mit den Hilfen angefertigt, die ich in der Dissertation angegeben habe. Alle Textstellen, die wörtlich oder sinngemäß aus veröffentlichten Schriften entnommen sind, und alle Angaben, die auf mündlichen Auskünften beruhen, sind als solche kenntlich gemacht. Bei den von mir durchgeführten und in der Dissertation erwähnten Untersuchungen habe ich die Grundsätze guter wissenschaftlicher Praxis, wie sie in der „Satzung der Justus-Liebig-Universität Gießen zur Sicherung guter wissenschaftlicher Praxis" niedergelegt sind, eingehalten."

Giessen, February 01, 2012 **Muhammad Ijaz**

Der Lebenslauf wurde aus der elektronischen Version der Arbeit entfernt.

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I am finally to admit that errors that remain are mine

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