Effect of some agrotechnical factors on yield and yield structure of oilseed rape composite hybrids

Marek WOJTOWICZ, Franciczek WIELEBSKI

Plant Breeding & Acclimatization Institute, (IHAR)
Strzeszyńska 36, 60-479 Poznań, Poland.

Introduction

Oilseed rape is the main oil plant cultivated in Poland. In 2001 cultivation area of winter rape amounts to about 395 thousand ha. The most significant commercial character of the plant, crucial for cultivation profitability is yield. One of the possibilities of oilseed rape yield improvement is hybrid cultivar breeding. The best hybrids showed yield performance 10 to 20% higher than standard cultivars. To obtain heterosis effect a system perfectly controlling cross pollination is needed. Among the systems controlling cross pollination in oilseed rape the gene-cytoplasmic male sterility CMS ogura controls cross pollination in a hundred per cent. Unfortunately, the creation of hybrid cultivars by CMS ogura system is limited because of the lack of valuable restorer lines. Difficulty in finding of valuable restorer lines influences the progress of investigation on possibility of composite hybrid introduction into farming in Poland. High yield of composite hybrids Synergy and Coctail bred in France (1994, 1995) and Canon in Denmark (1995) showed usefulness of such study. In Poland research and breeding work was successfully finished in 2001. Two new composite hybrids were registered: Mazur and Kaszub.

Material and Methods

Two series of three field experiments were carried out in three Experimental Stations of Plant Breeding and Acclimatization Institute: Borowo, Łagiewniki, Oleśnica Mała in 1997/98 and 1998/99. Effect of sowing density (70, 140, 230 seeds per sq. m.), percentage of pollinator seeds (5, 10, 20, 30, 40, 50%), sowing date (early, optimum, late), spring (80, 160 kg N/ha) and autumn nitrogen fertilization (0, 20, 40, 60 kg N/ha) on development, wintering and yield of composite hybrids was investigated. The subject of this study were two non-restored hybrids:

- POH 495 composed of hybrid FPO1 and pollinator: strain MAH 15
- POH 595 composed of hybrid FPO1 and pollinator: variety Bor.

The trials were laid out on brown and grey-brown podzolic soils belonging to IIa-IVa soil quality class. In all places oilseed rape was sown after cereals. After sowing, before and after winter and after harvest on each plot at two random 2 metre long sections, the number of plants per area unit was measured. Survival rate of pollinator and male sterile hybrid plants was measured by comparison of a number of plants in the flowering time with a number of germinating seeds per sq. m. During flowering on each plot in three random places 50 plants were evaluated and male sterile and pollinator plants were marked. 5 male sterile and 5 pollinator plants were taken at random from each plot and the following structural components and morphological characters of each plant were measured: number of properly developed and empty pods per plant, number of seeds per pod, weight of 1000 seeds, branch number and plant height. After harvest yield of each plot, fat and glucosinolate content in seeds were measured. Data were analysed with Tukey's multiple range test (P=0,05).

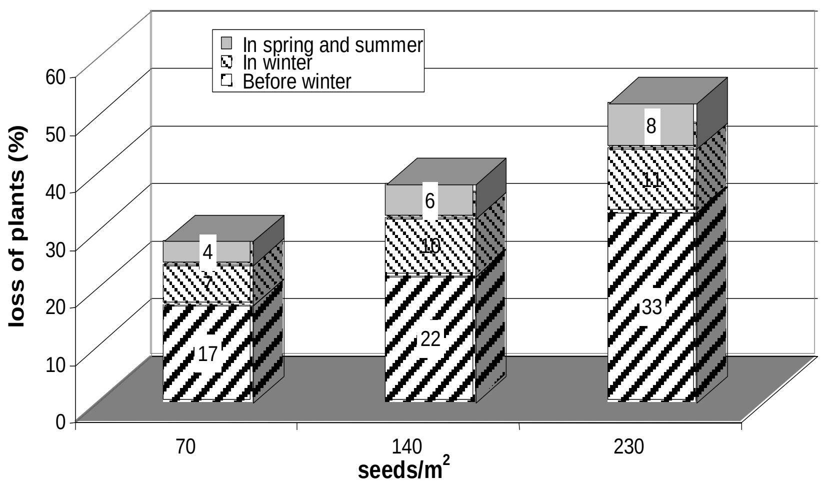
This study was undertaken in order to determine the response of oilseed rape composite hybrids to sowing rate, percentage of pollinator seeds, sowing date, autumn and spring nitrogen fertilization.

Results and Discussion

Sowing rate significantly determined plant density. Essential reduction of plant density took place in autumn. Changes of plant number during winter and spring were smaller. Furthermore, reduction of plant density was not proportional to seeding rate. The biggest losses of plants (more than 50%) occurred on plots at the highest sowing rate (230 seeds per sq. m.). Losses of plants on plots at the sowing rate of 140 and 70 seeds per sq. m. resulted in 38 and 28 % , respectively (Fig. 1).

Fig. 1

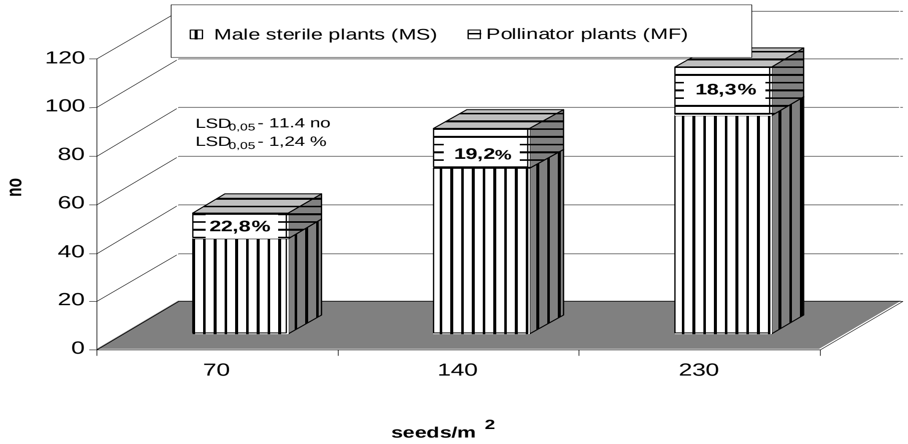
Loss of plants in particular vegetation periods according to sowing density



Sowing rate also influenced pollinator plant survival. Percentage of pollinator plants was reduced as sowing rate increased. This dependence resulted from different vigour of composite hybrid components. Male sterile plants characterized by better vigour were more competitive than pollinator plants, so pollinator development on higher density-plots was more suppressed (Fig. 2).

Fig. 2

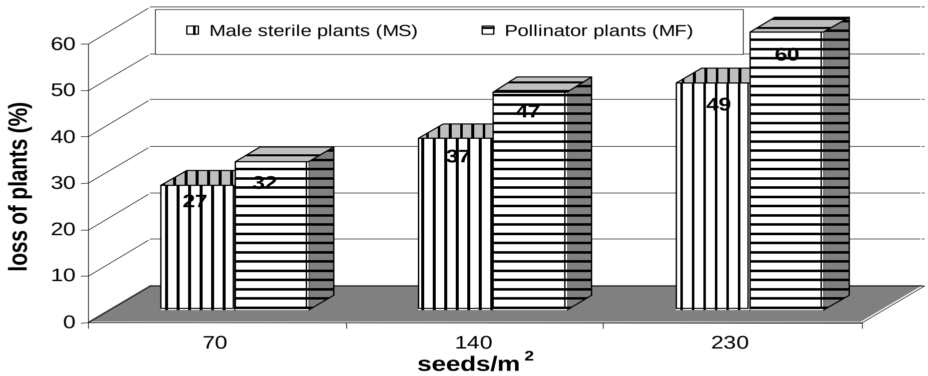
Number of composite hybrid plants in spring and percentage of pollinator plants according to sowing rate



Losses of pollinator and male sterile plants were similar on the plots at sowing density of 70 seeds per sq. m. Increasing sowing density increased losses of pollinator plants in comparison with male sterile plants (Fig. 3).

Fig. 3

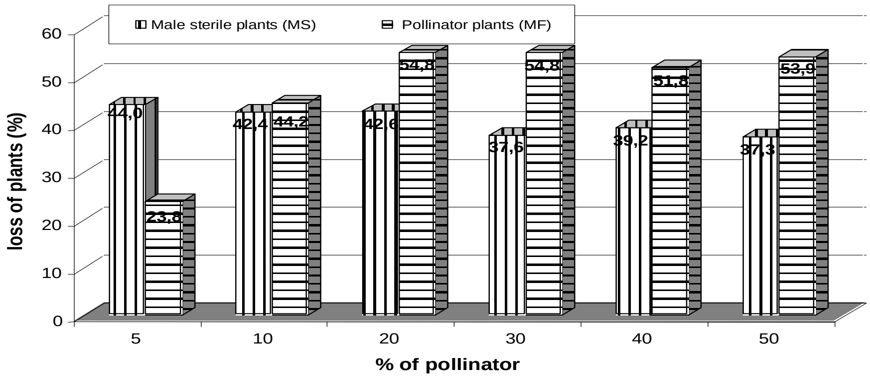
Loss of pollinator and male sterile plants from emergence to flowering according to sowing rate



Survival of pollinator plants was also dependent on their percentage in composite hybrid. The loss of pollinator plants was increased significantly when percentage of pollinators was raised from 5 to 20%. Further increase of pollinator percentage did not significantly influence pollinator plant survival (Fig. 4).

Fig. 4

Loss of pollinator and male sterile plants according to percentage of pollinator in composite hybrid POH 595

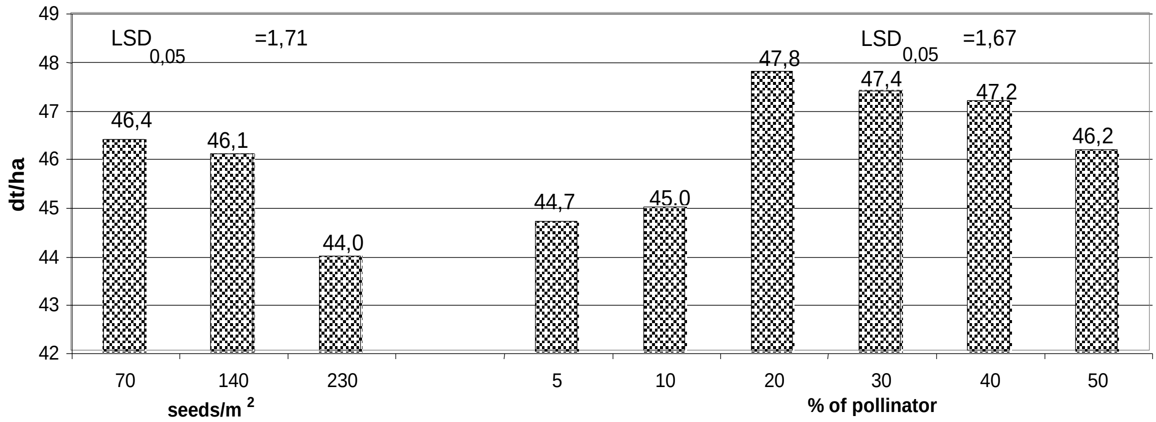


The experiment showed significant effect of sowing density on yield level (Fig. 5). The highest yield level was achieved at the sowing rate of 70 seeds per sq. m. Not significant decrease of yield was noticed on the plots at the sowing rate of 140 seeds per sq. m. Increase of sowing density to 230 seeds per sq. m. caused an essential yield reduction.

The yield was also dependent on the percentage of pollinator plants (Fig. 5). The highest yield was noticed on the plots at 20 percentage of pollinator plant seeds. These results were consistent with those reported by Pinochet (1995). Weather conditions during flowering promoted good plant fertilization, particularly in the first year of investigation. It is considered that in worse weather conditions (coolly, wet weather) higher per cent of pollinator plant seeds is more advisable. Therefore more safety appears association of 30 per cent of pollinator seeds and 70 per cent of male sterile hybrid plant seeds.

Fig. 5

Seed yield of composite hybrid POH 595 according to sowing density and percentage of pollinator



Sowing rate and percentage of pollinator seeds significantly affected yield structure of male sterile plants and pollinator plants. Sowing rate influenced mostly the number of pods. Changes of other yield components were smaller but significant (Table 1).

Table 1

Effect of sowing rate on yield components of male sterile and pollinator plants

Sowing rate (seeds per sq.m.)	Number of plants before harvest per sq.m.	Number of properly developed pods per plant	Percentage of properly developed pods	Number of seeds per pod	Weight of 1000 seeds (g)	Weight of seeds per pod (mg)
Male sterile plants - MS						
70	39,7	207,7	64,6	15,7	5,89	82,7
140	68,7	129,4	64,5	14,0	5,79	73,2
230	90,3	104,8	66,8	13,4	5,45	65,9
$LSD_{0,05}$	21,4	9,95	1,82	1,11	0,40	5,43
Variation coefficient (%)	31,3	54,8	1,5	6,7	3,3	9,3
Pollinator plants - MF						
70	10,4	118,3	65,0	20,5	4,03	81,4
140	16,3	69,8	60,8	20,9	3,96	82,2
230	20,2	58,7	65,1	18,7	3,97	73,6
$LSD_{0,05}$	3,4	6,01	1,90	1,15	n.s.	5,47
Variation coefficient(%)	25,8	31,5	4,90	4,7	0,8	4,9

Percentage of pollinator seeds significantly influenced the number of pods per plant, the number of seeds per pod and the weight of 1000 seeds of male sterile plants (Table 2). The weight of 1000 seeds was characterised by higher variability than the number of seeds per pod. The least changeable feature was the weight of seeds per pod. With the increase of pollinator percentage the weight of 1000 seeds of male sterile plants decreased.

Table 2

Effect of percentage of pollinator seeds on yield components of male sterile hybrid plants

Percentage of pollinator seeds	Number of plants before harvest per sq.m.	Number of properly developed pods per plant	Percentage of properly developed pods	Number of seeds per pod	Weight of 1000 seeds (g)	Weight of seeds per pod (mg)
5	78,2	140,0	62,2	13,4	6,22	78,2
10	76,2	160,0	67,4	13,8	6,03	74,1
20	67,5	151,2	68,2	13,4	5,74	69,9
30	64,2	153,2	71,5	15,8	5,11	74,0

40	53,6	149,6	70,4	16,0	4,73	71,4
50	46,1	147,1	72,4	16,2	4,60	70,3
$LSD_{0,05}$	2,1	19,1	2,67	1,51	0,828	n.s.
Variation coefficient(%)	18,7	6,7	7,9	11,1	17,9	5,2

Significant differences between yield structure of pollinator and male sterile hybrid plants were noticed (Table 3). This data confirmed CETIOM (1994) results that heterosis effect mainly referred to number of pods. Male sterile hybrid plants produced over 50% more pods than pollinator plants. Studies carried out by Piątek (1999) on composite hybrid of spring oilseed rape also demonstrated that heterosis effect appears mainly in number of pods per plant. It is very important because yield level of oilseed rape first of all is dependent on number of pods per plant what was proved by Shrimpf (1954), Stolle (1954), Olson (1960), Thurling (1974) and Musnicki (1989), Wójtowicz *et al.* (1999). Moreover, in male sterile hybrid plants percentage of properly developed pods was higher. Pods of these plants produced fewer but bigger seeds. Ramsbotton and Kihhtley (1999) suggested that the smaller seed weight of the pollinator seed might be attributable to reduced access to light, water and nutrient.

Furthermore male sterile hybrid plants were higher and had more branches (Table 4). Busch (1995) comparing ten composite hybrids with their parents also showed that composite hybrids were higher and had more branches and pods.

Table 3

Yield structure of male sterile hybrid and pollinator plants

Component	Male sterile hybrid	Pollinator	$LSD_{0,05}$
Number of properly developed pods per plant	150,2	82,3	7,10
Number of empty pods per plant	74,7	46,7	4,50
Number of pods per plant	224,9	129,0	10,31
Percentage of properly developed pods per plant	68,7	64,8	1,00
Number of seeds per pod	14,8	20,0	0,66
Weight of 1000 seeds	5,71	3,99	0,24

Table 4

Morphological characters of male sterile hybrid and pollinator plants

Morphological character	Male sterile hybrid	Pollinator	$LSD_{0,05}$
Branch number	4,3	3,1	O,18
Plant height (cm)	152,4	148,7	1,27

The experiment showed that percentage of pollinator plants significantly influenced seed quality of the composite hybrids (Table 5). Seeds from the plots at 30 percentage of pollinator plants were characterised by the highest content of oil and low content of glucosinolate. Percentage of more harmful alkenyl glucosinolate decreased at 30 percentage of pollinator plants. Sowing density had not significant effect on quality of seeds.

Table 5

Effect of percentage of pollinator plants on seed quality of composite hybrid POH 595

Percentage of pollinator plants	Content of fat (%)	Total glucosinolates (μM/g seeds)	Alkenyl glucosinolate content (μM/g seeds)	Percentage of alkenyl glucosinolate content (%)	Indol glucosinolate content (μM/g seeds)
5	46,1	19,0	16,1	84,7	2,94
10	46,8	14,9	12,5	84,0	2,41
20	47,3	13,3	11,1	83,4	2,22
30	48,0	12,0	9,4	78,3	2,58
40	47,4	10,7	8,2	76,6	2,54
50	47,8	11,1	8,4	75,7	2,61
$LSD_{0,05}$	1,05	1,85	1,65	3,92	n.s.

Sowing date affected the character of hibernating plants. The number of leaves per rosette, the diameter of root collar, the elevation of shoot apex, the fresh matter of plants decreased when time of sowing was late (Table 6). There was not significant difference between cultivars. Significant differences were noticed between locations of experiments. It was the effect of weather conditions during sowing and autumn vegetation period. Oilseed rape in Oleśnica had more leaves, greater diameter of root collar, higher elevation of shoot apex and grater fresh matter of plants than oilseed rape cultivated in Borowo and Łagiewniki. Sowing date did not influence significantly plant population density before winter and in spring and did not also affect survival rate of pollinator plants.

Table 6

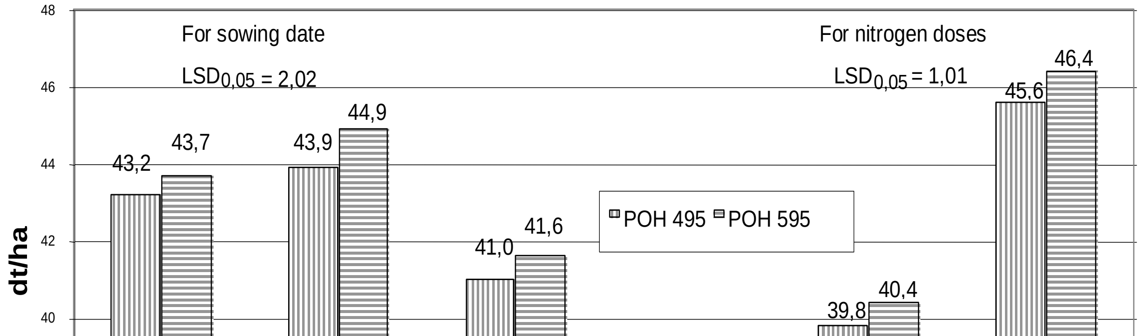
Effect of sowing date on morphological character of plants before winter

Sowing date	Number of leaves per plant	Diameter of root collar (mm)	Elevation of shoot apex (mm)	Fresh matter of plants (g)
early	7,64	6,65	25,6	357,6
optimum	7,72	5,26	19,9	221,6
late	6,97	4,33	16,2	143,3
$LSD_{0,05}$	0,556	0,401	2,98	43,51

Sowing date and spring nitrogen fertilization had significant effect on yield of two investigated composite hybrids (Fig. 6). 7 day delay of sowing after optimum sowing date caused significant yield decrease of two investigated cultivars. The increase of spring nitrogen dose from 80 to 160 kg N/ha caused significant increase of seed yield. High yield level at the dose of 80 kg N/ha can give evidence to big ability of composite hybrids to nitrogen utilization. The influence of sowing date and spring nitrogen fertilization on seed yield of conventional varieties was investigated by many authors. Experiments carried out by Majkowski *et al.* (1983), Budzyński *et al.* (1985b), Jasińska *et al.* (1985) and Muśnicki (1989) showed that the delay of sowing cause decrease of seed yield while the results obtained by Horodyski *et al*. (1983) does not confirm this dependence. Budzyński *et al.* (1985b) and Horodyski *et al.*. (1986) proved that the effect of sowing date on seed yield is dependent on weather conditions during winter. According to these authors the delay of sowing after optimum sowing date caused significant yield reduction only after frosty winters. Muśnicki (1989) suggested that different effect of sowing date on seed yield of oilseed rape resulted from the influence of weather conditions during rosette creation, wintering and spring development of plants. It is commonly known that among all nutrients nitrogen has the highest effect on yield level. However, authors disagree about the response of varieties to spring nitrogen fertilization. Budzyński *et al.* (1983, 1985a), Muśnicki, Jodłowski (1986) and Barszczak, Barszczak (1995) considered that the response of varieties to spring nitrogen fertilization is similar while Szukalski *et al.* (1988) state, that varieties differ in nitrogen absorption and utilization. Experiment results of Gerath and Schweiger 1991, Barszczak *et al.* 1990, 1991a, 1991b and Spasibionek *et al.* 1996 suggest that the ability of using nitrogen has a genetic cause.

Fig. 6

Effect of sowing date and spring nitrogen fertilization on seed yield of composite hybrids POH 495, POH 595



Sowing date had not significant effect on seed quality of composite hybrid while higher nitrogen dose significantly increased protein content and decreased fat content. Moreover cultivars differed in glucosinolate content (Table 7). This difference resulted from a pollinator type. Seeds of POH 595 were characterized by smaller content of glucosinolate because pollinator – BOR has smaller level of these substances than MAH 15. The effect of spring nitrogen fertilization on the increase of protein content and decrease of fat content of conventional varieties is showed by Barszczak, Barszczak (1995), Muśnicki *et al.* (1999), and Wielebski, Wójtowicz (1998).

Table 7

Effect of sowing date and spring nitrogen fertilization on seed quality of composite hybrids

Factor	Content of fat (%)	Content of protein (%)	Total glucosinolates (μM/g seeds)	Alkenyl glucosinolate content (μM/g seeds)	Percentage of alkenyl glucosinolate content (%)
Sowing date					
early	43,8	19,4	11,8	8,95	75,8
optimum	46,0	19,7	12,1	9,20	76,0
late	45,5	19,7	11,6	8,81	75,9
$LSD_{0,05}$	n.s.	n.s.	n.s.	n.s	n.s.
Nitrogen dose (kg N/ha)					
80	46,1	19,2	11,4	8,78	77,0
160	44,1	20,0	12,2	9,18	75,2
$LSD_{0,05}$	0,80	0,45	n.s.	n.s.	n.s.
Cultivar					
POH 495	44,9	19,4	13,2	10,3	78,0
POH 595	45,3	19,8	10,5	7,64	72,8
$LSD_{0,05}$	n.s.	n.s.	1,15	1,03	4,26

Nitrogen applied before sowing had significant effect on the number of leaves per rosette, the diameter of root collar, the elevation of shoot apex and the fresh matter of plants (Table 8). These morphological characters of plants increased according to nitrogen dose increase. Estimation of the influence of these plants morphological characters on wintering was not fully possible because of mild winters during years of investigations.

The number of plants per sq.m. before winter and spring, wintering and survival rate of pollinator was not dependent on nitrogen applied before sowing. The study showed significant effect of nitrogen applied before sowing on yield of two composite hybrids (Table 9). The highest yield was achieved at 20-40 kg of nitrogen applied before sowing. Relinquishment of seedbed nitrogen application caused significant yield reduction.

Table 8

Effect of seedbed nitrogen fertilization on morphological character of plants before winter

Nitrogen dose (kg N/ha) Cultivar	Number of leaves per rosette	Diameter of root collar (mm)	Elevation of shoot apex (mm)	Fresh matter of plants (g)
0	7,59	5,48	20,4	246,3
20	7,74	5,65	20,4	271,6
40	7,81	5,80	22,3	305,4
60	8,04	6,21	23,1	342,6
$LSD_{0,05}$	0,21	0,28	1,78	37,6
POH 495	7,85	5,79	21,0	286,3
POH 595	7,74	5,78	22,1	296,7
$LSD_{0,05}$	n.s.	n.s.	n.s.	n.s.

Table 9

Effect of seedbed nitrogen fertilization on yield of composite hybrids

Nitrogen dose (kg N/ha)	Yield (dt/ha)	
	POH 495	POH 595
0	49,9	48,8
20	53,2	50,1
40	52,7	53,7
60	51,8	50,6
$LSD_{0,05}$	3,01	2,98

Nitrogen applied before sowing affected pod production of both pollinator and male sterile plants and had not an effect on other yield components. Glucosinolate, fat and protein content in seeds of investigated composite hybrids was not dependent on seedbed nitrogen doses.

Conclusions

- **Yield was dependent on sowing rate, pollinator percentage and the level of nitrogen fertilization.**
- **The highest yield was achieved at the sowing rate of 70 seeds per sg.m., 20-30 per cent of pollinator seeds in composite hybrid, 20-40 kg of nitrogen applied before sowing and 160 kg of nitrogen applied in spring.**
- **Sowing rate, sowing date, nitrogen fertilization before sowing had significant effect on morphological characters of plants before winter.**
- **The influence of plant morphological characters on wintering was not proved because of mild winters during years of investigations.**

- **Survival rate of pollinator plants was mainly dependent on sowing rate, less dependent on pollinator type and percentage of pollinator in composite hybrid.**
- **Sowing date and seedbed nitrogen fertilization had not significant effect on survival rate of pollinator.**
- **Sowing rate, percentage of pollinator plants, sowing date and spring nitrogen fertilization affected the yield components of pollinator and male sterile plants.**
- **Heterosis effect mainly depended on the number of pods per plant.**
- **30 per cent of pollinator plants in composite hybrid is recommended because this percentage ensured adequate amount of pollen and the best quality of harvested seeds and also do not decrease heterosis effect.**

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