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IMPACT OF CROP AND WEED DENSITIES ON COMPETITION BETWEEN WHEAT AND *SILYBUM MARIANUM* GAERTN.

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Abstract

Field trials were conducted at Peshawar, Pakistan during two crop seasons i.e. 2003-04 and 2004-05 using a Randomized Complete Block (RCB) design with split-plot arrangement. The main plots consisted of four seed rates of wheat (*Triticum aestivum* L.) i.e. 100, 120, 140 and 160 kg ha^{-1}, while sub-plots had 7 densities of the weed holy thistle (*Silybum marianum* Gaertn.) viz., 0, 3, 6, 9, 12, 15 and 18 plants m^{-2}. Holy thistle was more aggressive during second year as compared to first year, mainly due to unusual rainfall (140 & 317 mm in year 1 & 2, respectively), which in return affected the yield and yield related traits in wheat. Crop yield losses with increasing weed density were greater with lowest crop populations. The results of grain yield losses caused by the weed at different densities in two trials indicated that both species caused a density-dependent yield loss which is better explained by weed dry weight. Percent light interception increased with increasing wheat or weed density, however, weed density beyond 6 m^{-2} had no significant effect on percent light interception. Higher fresh and dry biomass of wheat was recorded in medium sowing rates (120 &140 kg ha^{-1}). As a result, higher fresh and dry biomass of the weed was recorded in low wheat density rather than high seeding density. All of the agronomic characters decreased with increasing the density of either species. Higher values of reproductive and vegetative characters of the weed were recorded in the second year as compared to that in the first year, and highest grain yield was obtained with wheat seeding rate of 120 kg ha^{-1}. Maximum yield losses at seed rate 100, 120, 140 and 160 kg ha^{-1} were 26, 18, 15 and 7% during 2003-04 and 37, 31, 28 and 29 % during 2004-05. Weed seed production was related with weed biomass which was dependent on wheat density; the higher the wheat density, the lower was the weed biomass. However, there was still a large seed production even at the highest wheat density. Thus, crop density alone could not suppress the weed below threshold level. The weed reduced wheat yield chiefly by the indirect effect of decreasing wheat tillers, the earliest formed yield component. The weed density, which resulted in yield losses varied greatly with density and season.

Introduction

Holy thistle (*Silybum marianum*), a plant having medicinal value is becoming a noxious weed not only along the roadsides but now is seen infesting the agricultural lands. *Silybum* is becoming a serious and aggressive weed of wheat like *Avena fatua* in irrigated districts of North-West Pakistan (Marwat, 2003). On the other hand several organizations involved in the conservation of nature, have introduced this species in national parks for conservation. It will not be out of place to say that letting Holy thistle grow violates every accepted conventional agricultural practice. Once *Silybum* has found a niche, it is a competitive thistle and tends to establish in tall dense patches that eliminate other plant species either by shading or by competition for moisture and nutrients. *Silybum* spreads by seed, which is about the size of a grain of wheat, thus imperfectly cleaned, or uncleaned cereal seed is a common means of spread. It is found in waste areas, pastures and occasionally in crops and grows best in areas of high fertility.

The large, vigorous rosettes of Holy thistle are strongly competitive in pastures and crops causing severe yield losses. *Silybum* develop slowly through the seedling stage, becoming flat rosettes by late autumn/early winter. Growth is rapid in late winter and early spring, producing large cabbage-like plants up to 3 feet in diameter from which center stems develop in spring (Parsons, 1973).

A successful integrated and sustainable weed management program for the control of *Silybum* cannot be implemented without a clear understanding of inter-specific competition between *Silybum* and major winter crops. For this purpose, a good knowledge of population dynamics of *Silybum* is also a necessity. Similarly higher seed rate play a vital role in suppressing weeds but the yield is decreased above optimum seed rate. In higher crop densities, there is potential to suppress weeds because increasing density within rows increases intraspecific competition within the crop population more than it increases competition with the weeds (Weiner *et al*., 2001). Caution should be taken when estimating crop yield loss solely on weed density in bioeconomic weed management models (Lindquist *et al*., 1996). Wheat yield loss is due to nitrogen concentration, biomass and density of Canada thistle (Mamolos & Kalburtji, 2001). Canada thistle infestations of 15 to 20 shoots m^{-2} can reduce wheat yields by as much as 36% (Darwent *et al*., 2006). Higher seeding rates accelerate phenological traits (Henson & Lukach, 1992) but decrease tillers, spikes $plant^{-1}$ and grains $spike^{-1}$ (Dofing & Knight, 1992). Seeding rate and weed control are the deciding factors for canopy architecture, light interception and consequently for modifications of yield components and finally yield (Turk & Tawaha, 2002). Increasing Canada thistle (*Cirsium arvense*) density decrease wheat stand chiefly by decreasing wheat density (Donald & Khan, 1996). Wheat yield was reduced 47% at the highest density of 12 common milkweed (*Asclepias syriaca*) shoots m^{-2} (Yenish *et al*., 1997). More weeds resulted in higher weed dry weight (Moore *et al*., 2004).

Many studies have documented the effects of densities of different weed species on the reduction of wheat yield. However, there is no report in the literature about the *Silybum*/wheat competition. The present experiments were therefore conducted to determine the effects of various densities of *Silybum* and wheat at a range of densities.

Materials and Methods

Field trials were conducted at Agricultural Research Farm, NWFP Agricultural University Peshawar, Pakistan for two cropping seasons i.e., 2003-04 and 2004-05. Peshawar lies between 71^0 E and 33^0 N and is located at 317 m height above sea level. The experimental site had soil pH of 7.5 having clay 22.8%, 55.7%, silt 21.5% and sand. Wheat was seeded in November each year, using hand hoe and the rows were spaced at 30 cm apart. The experiments were conducted using a Randomized Complete Block (RCB) design with split-plot arrangement, having four main plots and seven sub-plots, replicated four times. The main plots had four seed rates of wheat i.e. 100, 120, 140 & 160 kg ha^{-1} (280, 336, 392 & 448 m^{-2}) while sub-plots had seven densities of Holy thistle (*Silybum marianum*) i.e., 0, 3, 6, 9, 12, 15 and 18 plants m^{-2}. Seeds of *Silybum* were planted manually, the same day as the wheat and were accommodated in the treatments at equal distance. To avoid any risk of germination failure, 3 to 5 seeds of *Silybum* were planted instead of a single one. The germination percentage of each species was pre-tested and then seed rate were adjusted accordingly. The germination of both species of plants were observed and extra plants of *Silybum marianum* were removed. The wheat plants from three central rows were harvested, threshed, cleaned and weighed to record the grain yield kg ha^{-1}. Random sample of 10 plants of *Silybum* was collected, and the mean was calculated. Thus mean of 10 *Silybum* plants was kept in oven for 72 hrs at 70 ^{0}C and then the data was converted into kg ha^{-1}.

Percent light interception (PLI) was calculated as PLI = (I–It/I0) x 100, where It is incident photosynthetically active radiation (PAR) just below the lowest layer of PAR and I0 is incident PAR at the top of the canopy. The values of It and I0 was obtained with the help of PAR Meter (Digital Lux Meter, Germany). The data was recorded at milk stage of the wheat grains and repeated five times. The readings were confined to the mid day (1100–1300 h) on sunny days only. Such readings were averaged and percent light interception (PLI) was calculated, using the above mentioned formula. All other weeds were removed manually throughout the wheat season on weekly basis. Nitrogen and phosphorus fertilizers in the form of Urea and Diamonium phosphate (DAP) were applied @ of 135:50 NP. Half N and full dose of P was applied at sowing and remaining N was applied at second irrigation in each experiment.

Data analysis: Combined analysis was done but as the year's effect was significant, therefore data was subjected to two factor analysis of variance (ANOVA), as per design requirement, using a computer software MSTATC (Michigan State University, USA). To further assess the difference between the means, Least Significant Difference (LSD) test was applied using the above mentioned software. As the levels of treatments were spaced at equal interval, therefore the interaction of seed rates and *Silybum* densities were subjected to regression analyses using EXCEL spreadsheet package to determine the trends and thus regression lines were fitted accordingly.

Results and Discussion

Grain yield (kg ha^{-1}): ANOVA showed that during both the years (2003-04 & 2004-05), maximum grain yields (3155 and 3049 kg ha^{-1}, respectively) were recorded at seed rate 120 kg ha^{-1}. The grain yields in all other seed rates were statistically at par during 2003-04, and decreased with the increase in seed rate above 120 kg ha^{-1} during 2004-05. These results reflect that *Silybum* proved more competitive at higher seed rates during 2004-05 due to higher rainfall and lower temperature (Table 1) during 2004-05. It seems that *Silybum* thrives best at lower temperature and high moisture as these conditions also favoured wheat but unlike the *Silybum* during 2004-05. The grain yield decreased due to intraspecific as well as interspecific competition (Table 2). A decrease in grain yield was observed with the increase in *Silybum* density, however it was dependent upon rainfall and temperature. During both the years, even the lowest *Silybum* density (3 m^{-2}) decreased the grain yield but this reduction was much more during 2004-05 (high rainfall and low temperature) as compared to 2003-04 (low rainfall and high temperature). Means of the data showed maximum reduction (17 & 32%) at *Silybum* density 18 m^{-2} during 2003-04 and 15 m^{-2} during 2004-05, respectively. Linear response range at low densities and a maximum yield loss of 90% at high weed densities were found (Harrison *et al*., 2001). This indicates that *Silybum* attained its maximum growth earlier than wheat during 2004-05 exerting greater canopy coverage over the wheat crop and resulting in enhanced competition for nutrients and light.

Table 1. Weather data (temperature and precipitation) of experimental site.

Year	Month		Temperature (°C) Max (mean)	Temperature (°C) Min (mean)		Precipitation (mm)
2003-04	December		1.2	6.0		9.5
	January		18.0	4.2		55.1
	February		23.1	6.3		39.4
	March		28.6	10.7		00.0
	April		31.0	16.5		36.7
		Mean	**24.8**	**8.74**	**Total**	**140.7**
2004-05	December		20.7	6.3		25.8
	January		16.9	3.3		75.9
	February		16.4	5.1		97.4
	March		22.1	10.8		108.5
	April		29.3	12.54		9.3
		Mean	**21.1**	**7.6**	**Total**	**316.9**

Source: Weather Station, NWFP Agricultural University Peshawar, Pakistan

Table 2. Means of seed rates and *Silybum* densities during 2003-04 and 2004-05.

	Grain yield of wheat ($Kg\ ha^{-1}$)		Weed Dry biomass ($Kg\ ha^{-1}$)		Light interception (%)	
	2003-04	**2004-05**	**2003-04**	**2004-05**	**2003-04**	**2004-05**
Seed rate ($Kg\ ha^{-1}$)						
100	2882 B	2845 B	2070 A	2162 A	87.1 B	89.3 B
120	3155 A	3049 A	2014 A	2011 AB	91.0 A	91.1 AB
140	2891 B	2725 C	1756 B	1903 B	92.2 A	91.0 AB
160	2933 B	2564 D	1519 C	1627 C	93.0 A	92.1 A
LSD values	111.7	110.9	117.8	154.3	3.002	1.880
Weed density m^{-2}						
0	3334 A	3533 A	0.00 E	0.00 D	85.6 B	82.3 D
3	3137 B	3081 B	1713 D	2013 C	87.7 B	86.7 C
6	3022 B	2901 C	1998 C	2092 C	92.7 A	92.0 B
9	2899 C	2706 D	2137 B	2252 B	92.5 A	92.6 AB
12	2823 CD	2527 E	2306 A	2320 AB	92.5 A	93.7 AB
15	2784 CD	2420 F	2341 A	2388 AB	92.9 A	94.6 A
18	2757 D	2402 F	2383 A	2414 A	91.7 A	94.3 A
LSD values	117	105.5	104.7	159.4	2.41	2.12
Interaction						
SR x WD	**	**	**	**	**	**

Values followed by different letters are significantly different at $p \leq 0.001$ levels according to LSD test.
SR = Seed rate
WD = Weed (*Silybum*) density
NS = Non-significant
** = Significant at $p \leq 0.001$

During 2004-05, higher rainfall enabled *Galium aparine* to escape suppression by wheat (Seavers & Wright, 1999). Large seasonal differences in wheat yield loss from densities of *Avena* spp. across 2 years due to a function of seasonal factors such as rainfall was recorded (Murphy *et al.*, 2002). Grain yields decreased with increasing number of weeds (Ibrahim *et al*., 1995; Ichizen *et al*., 1999). Interaction of *Silybum* density and wheat seed rates showed that during the two growing seasons (2003-04 & 2004-05), the interactions between *Silybum* density and wheat seed rates were affected differently. Although the grain yield at all seed rates were significantly affected but the magnitude of yield reduction was temperature and moisture dependent as well (Figs. 1&2). Based on weed relative leaf area, estimates of *Setaria faberi* or *Chenopodium album* damage coefficients in Soybean differed between years (Conley *et al*., 2003). The intercept showed that high rainfall positively affected the pure stand of wheat (Figs. 1&2). However, the environmental conditions favored the growth and development of *Silybum* and thus bigger values of slope (b) in regression equations were recorded during 2004-05 (Figs. 1&2). In both the years, the trend lines were in line but yield reduction at lower seed rate was more affected with increasing *Silybum* density during 2004-05. This might be due to severe interspecific competition. Wheat yield loss was due to biomass and density of Canada thistle (Mamolos & Kalburtji, 2001). Canada thistle (*Cirsium arvense*) infestations of 15 to 20 shoots m^{-2} can reduce wheat yields by as much as 36 % (Darwent *et al*., 2006). Although the seed of *Silybum* and wheat both were planted the same day but the emergence of wheat was earlier than *Silybum*. Thus during 2003-04 (lower rainfall and higher temperature), higher wheat densities suppressed the *Silybum* up to some extent and consequently less *Silybum* dry biomass were recorded. Greatly increased suppression of weeds by some crops through increased density can play an important role in a comprehensive strategy (Liebman & Gallandt, 1997). High seeding rates may result in an earlier competitive advantage over weeds compared with lower seeding rates (Ross & Harper, 1972). In both the years, wheat emergence was earlier than *Silybum* yet, the *Silybum* became dominant during 2004-05 and not during 2003-04 due to environmental conditions. Correlation coefficient (R^2) value decreased with increasing seed rate due to strong competitive ability of wheat at higher seed rates. The R^2 values ranged from 77-90 % during 2003-04 and 83-95% during 2004-05. Thus we can conclude that the time of emergence is important in crop/weed competition but it depends on the environmental conditions and specially the rainfall and temperature.

Dry Biomass (kg ha^{-1}): The maximum dry biomass of 2070 and 2014 kg ha^{-1} during 2003-04 and 2162 and 2011 kg ha^{-1} during 2004-05 was recorded at seed rate 100 and 120 kg ha^{-1}. With the increasing seed rate, the dry biomass of *Silybum* decreased significantly while with increasing *Silybum* density, the dry biomass increased only up to 12 m^{-2} in both the years (Table 2). The numerical values of dry biomass during 2004-05 are greater than 2003-04 probably due to more than two fold rainfall during 2004-05 (Table 1). These results showed that *Silybum* can prove more competitive if the rainy season prevails during the wheat growing season and hence *Silybum* will prove more competitive with the crop at any density. When the dry biomass of *Silybum* was regressed against its density, then it was noted that there was increase in dry biomass with the increase its density (Figs. 3&4). More weeds resulted in higher weed dry weight (Moore *et al*., 2004). However, the dry biomass of *Silybum* was greatly decreased by seed rate; higher the seed rate, lower was the dry biomass. *Silybum* attained more biomass during 2004-05 but the dry biomass do not reflect the whole assimilate in *Silybum* because the older leaves were shaded soon when the canopy closed over the wheat crop which resulted in senescence and dropping of older leaves. Leaves placed at lower strata of the canopy are exposed to low PAR and R:FR which accelerate leaf senescence (Rousseaux *et al*., 1996). Similarly, few plants in the same treatment achieved much more growth as

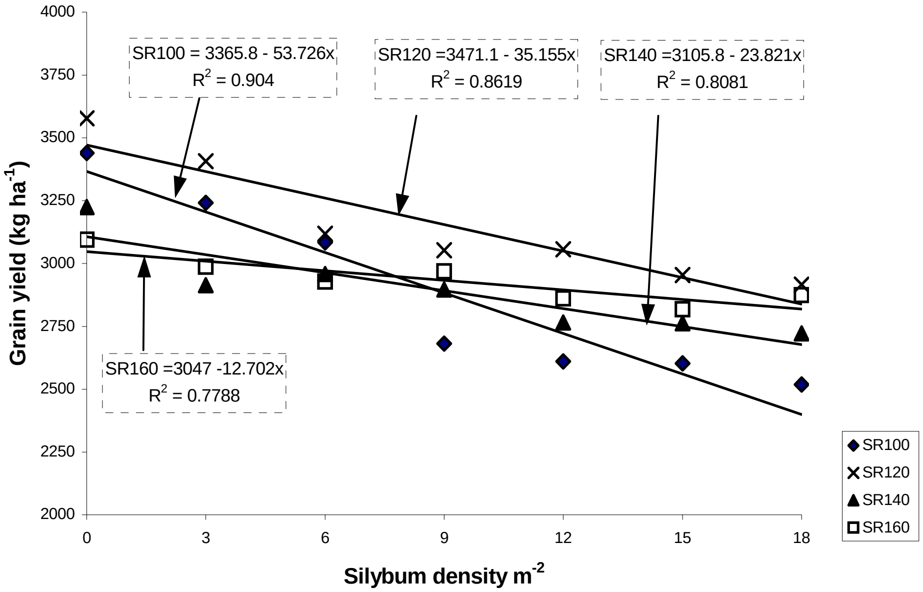

Fig. 1. Effect of seed rates and *Silybum* densities on grain yield of wheat during 2003-04.

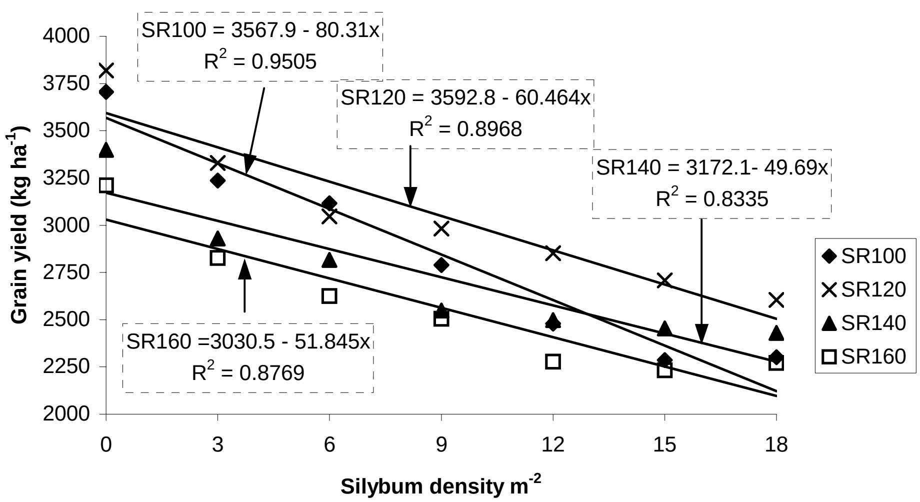

Fig. 2. Effect of seed rates and *Silybum* densities on grain yield of wheat during 2004-05.

compared to the other neighbour plants which is still a question. Slope (b) indicate that with the increase in seed rate, the dry biomass per unit increase in *Silybum* density, decreased due to intra-specific competition. Weed dry weight decreased with increasing seed rate (Gaffer *et al*., 1997). Dry weight of *Chenopodium album* were suppressed by increasing planting density or by the presence of crop (Grundy *et al*., (2004). In favourable meteorological conditions, the competitive ability of soybeans increased and *Echinochloa crus-galli* accumulated less biomass and thus main factors influencing the competitive relations were fresh and dry biomass of the weed (Stoimenova *et al*., 1994).

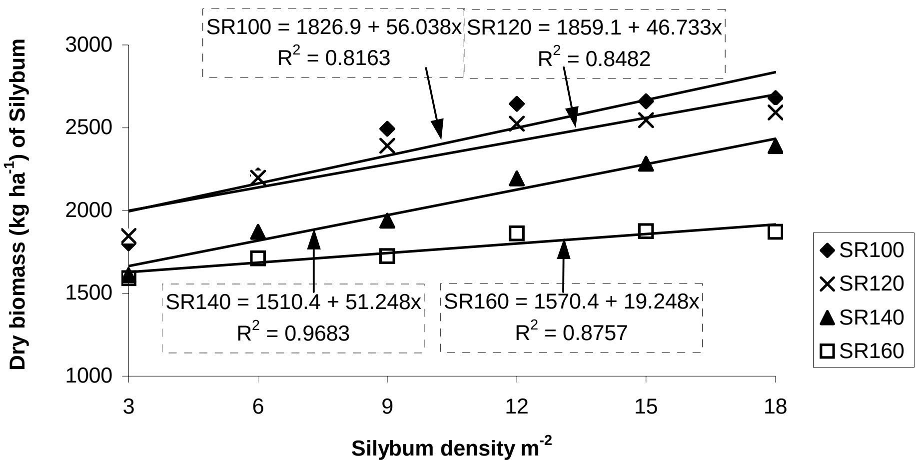

Fig. 3. Effect of seed rates and *Silybum* densities on dry biomass of *Silybum* during 2003-04.

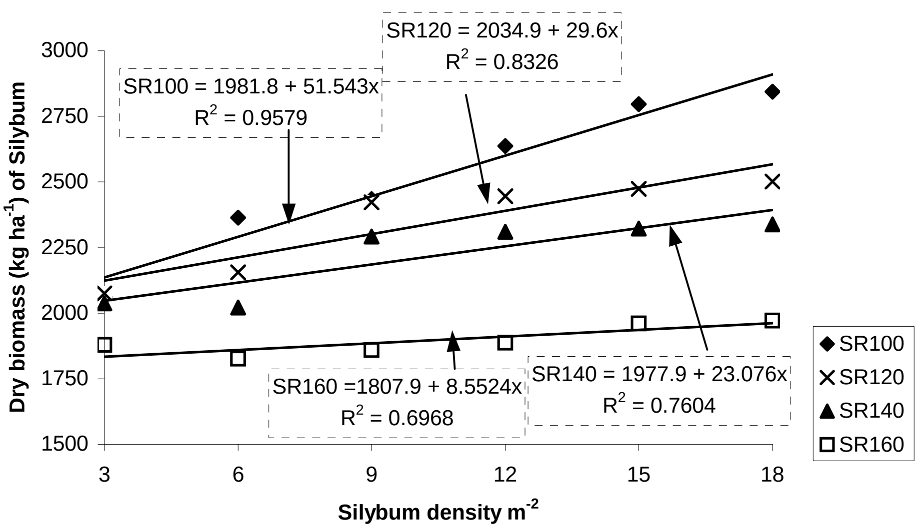

Fig. 4. Effect of seed rates and *Silybum* densities on dry biomass of *Silybum* during 2004-05.

Thus it can be concluded from the experiments that biomass production by weeds cannot be predicted in one way and other factors like precipitation and temperature should be included while developing model for weed biomass and grain yield of wheat. Dry weight of quackgrass proved to be the best predictor of potato yield loss compared to shoot number (Baziramakenga & Leroux, 1998). Light intensity strongly influenced the growth of Creeping thistle and little biomass was produced in constant shade (Fan & Gerowitt, 2002).

Percent light interception (PLI): Statistical analysis of the data showed that seed rate and *Silybum* density significantly ($P<0.001$) affected the light interception. In both the years, minimum light interception (87.1 and 89.3%) was recorded at seed rate 100 kg ha^{-1} while the values at all seed rates were statistically at par (Table 2). These results indicated that low crop density is unable to intercept more light due to lesser green area per unit area and hence yield is reduced. With the increase in *Silybum* density, the light interception increased upto 6 and 9 *Silybum* m^{-2} during 2003-04 and 2004-05, respectively which indicated that there was potential in *Silybum* to intercept more light during 2003-04 but the growth was restricted by nutrients limitation. While during 2004-05, maximum light was intercepted at 9 m^{-2} and thus more light was intercepted due to greater vegetative growth of *Silybum*. The bigger vegetative growth and higher competitive ability with the wheat was probably due to higher rainfall and low temperature during 2004-05 (Table 1). Incident radiation affect accumulation of dry matter in spike (Sabine & Jeuffroy, 2004). The light interception at *Silybum* density 3 m^{-2} was at par with pure stand of wheat during 2003-04 while significantly different during 2004-05 which indicate the bigger vegetative growth of *Silybum*. As light plays an important role in yield of crop, solar radiation is an essential determinant of crop yield in many ways (Ballare & Casal, 2000) therefore *Silybum* being inherently taller than wheat intercepted more light and thus the crop was deprived of sunlight. Although *Silybum* was not too much taller than wheat during 2003-04 but the number of leaves and leaf area intercepted more light while during 2004-05 the *Silybum* height was much more taller with more leaf area per plant, number of leaves and number of branches $plant^{-1}$.

Thus the crop was deprived of sunlight because there is close correlation between transmission of PAR and leaf area index (Rohrig & Stutzel, 2001). Light interception is directly proportional to wheat yield components (Abbate *et al*., 1997). Percent light interception was differently affected by different seed rates and *Silybum* density (Fig. 5&6). With the increase in *Silybum* density, the percent light interception (PLI) increased however the quadratic equations fitted best to describe the data, showing that there was a certain stage when maximum light was intercpeted and beyond that there was no more light interception due to drying and sheding of *Silybum* older leaves which decreased the PLI. Leaves at lower strata of canopy senescnece (Rousseaux *et al*., 1996). The decrease in yield and yield components of wheat can be attributed to the more light interception by the *Silybum* plants as the *Silybum* was much more taller than wheat during 2004-05, had greater leaf area and thus shaded the crop which consequently adversely affected the yield and yield components. The increasing light interception by *Silybum* plants showed that at the later stages of the crop, the *Silybum* mainly compete with the wheat for light and thus the yield components were negatively affected. The slight decline at highest *Silybum* density may be due to the leaves dropping at highest *Silybum* density. The increase in light interception due to unit increase in *Silybum* density was higher during 2004-05 as compared to 2003-04 (Fig. 5&6). These results confirm the higher vegetative growth of *Silybum* during 2004-05 due to environmental conditions. As the *Silybum* density increased the plant height of *Silybum* also increased due to more light interception and intra-specific competition which indirectly increased green area of *Silybum* as compared to wheat. Therefore the wheat crop was greatly negatively affected. There was significant effects of light on plant height, biomass, sprout number, root diameter and survival rate of *Cirsiun arvense* and constant shade reduced 58.6% of height and 99.5% of biomass (Fan & Gerowitt, 2002).

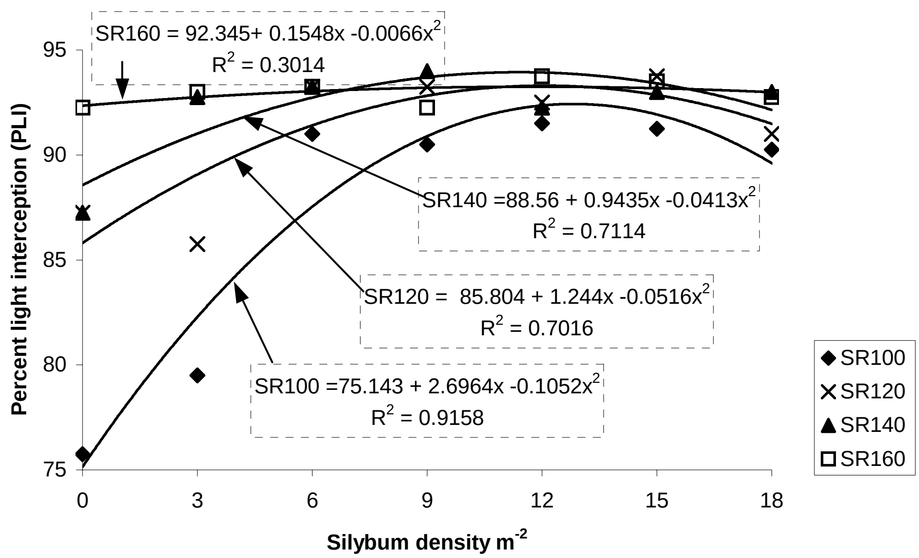

Fig. 5. Effect of seed rates and *Silybum* densities on percent light interception during 2003-04.

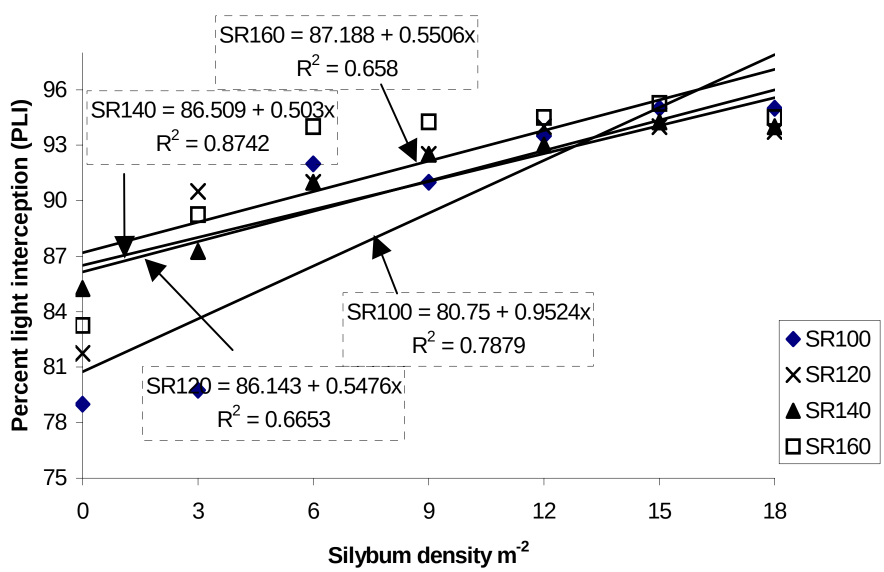

Fig. 6. Effect of seed rates and *Silybum* densities on percent light interception during 2004-05.

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