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Effect of Different Planting Pattern of (Rapeseed-Broad Bean) Using Replacement Series Method on Yield Performance of Rapeseed and Weed Biomass

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ABSTRACT

A field experiment was conducted to evaluate the competitive effects of different densities of rapeseed-broad bean intercropping on weeds growth and rapeseed yield at Shoushtar Agriculture, University in 2014. The experiment was performed in a completely blocks randomized design with four replications using replacement series in which broad bean and rapeseed were planted in different ratios of 100:0, 75:25, 50:50, 25:75 and 0:100 with a 20 bushes m^{-2}. Weed dry weight and weed density were reduced in intercropping system compared to rapeseed and bean sole crops. The most reduction in weed dry mass occurred in 50:50 ratio of rapeseed-bean intercropping. By increasing the density of rapeseed the seed yields, the number of pods in plant, the number of seeds in pods and the weight of 1000 seeds were increased. Evaluation of relative yield was higher than 1 in all mixture ratios. Based on competition indices rapeseed was of a less competitive ability than broad bean. Also, there was a significant negative correlation observed between broad bean density and rapeseed yield components which implies that a high density of broad bean up to 25% can cause serious yield reduction in rapeseed.

Key words: Broad bean, competition, rapeseed, replacement series

INTRODUCTION

Weed control is an important aspect in intercropping because chemical control is difficult once the crops have emerged. This is also because normally in intercropping a dicotyledonous crop species is combined with a monocotyledonous crop species and therefore the use of herbicides is problematic. In general, intercrops may show weed control advantages over sole crops in two ways. First, greater crop yield and less weed growth may be achieved if intercrops are more effective than sole crops in usurping resources from weeds (Olorunmaiye, 2010) or suppressing the growth of weeds through allelopathy. Alternatively, intercrops may provide yield advantages without suppressing the growth of weeds below levels observed in sole crops if intercrops use resources that are not exploitable by weeds or convert resources into harvestable materials more efficiently than sole crops. Intercropping may often result in reduced weed density and growth compared with sole crops (Liebman and Dyck, 1993). Intercrops that are effective at suppressing weeds capture a greater share of available resources than sole crops and can be more effective in pre-emptying resources by weeds and suppressing weed growth. Intercrops of *Sorghum* with fodder cowpea intercepted more light, captured greater quantities of macronutrients N, P and K produced higher crop yields and contained lower weed densities and less weed dry matter compared with sole cropped *Sorghum* (Abraham and Singh, 1984). Similarly, intercropping cassava with maize with nitrogen-fertilizer application gave the highest leaf area index and light interception and hence the best weed control, highest N, P and K uptake, total yields and Land Equivalent Ratio (Olasantan *et al*., 1994). Intercropping leek and celery in a row-by-row replacement design considerably shortened the critical period for weed control in the intercrop compared with the leek pure stand. Also, the relative soil cover of weeds that emerged at the end of the critical period in the intercrop was reduced by 41% (Baumann *et al*., 2000). Pea intercrops with barley instead of sole crop had greater competitive ability towards weeds and appeared as a promising practice of protein production in cropping systems with high weed pressures (Hauggaard-Nielsen *et al*., 2001). A significant reduction in weed density and biomass for the wheat/chickpea intercrops over both monocrops of wheat or chickpea was found (Banik *et al*., 2006). Mixed cropping peas with false flax in additive arrangements had a great suppressive effect on weed coverage, i.e., 63% in 2003 and 52% in 2004, compared with sole pea (Saucke and Ackermann, 2006). Intercropping single and double rows of *Sorghum*, soybean and sesame with cotton was effective in inhibiting purple nutsedge density (70-96%) and dry matter production (71-97%) (Iqbal *et al*., 2007). On conventionally managed land, mixtures of wheat and oatsand mixtures of wheat and barley at a seeding ratio 25:75 showed high yield potential than the monocrops, whereas barley mixtures also exhibited weed suppressive capabilities (Kaut *et al*., 2008). Farmers reported that intercropping maize with improved varieties of horse gram (*Macrotyloma uniflorum*) reduced labor since less weeding was required and in most cases did not have a yield-reducing impact on their maize crop or on the availability of fodder (Witcombe *et al*., 2008). The aim of the present study was to determining the proper ratio of rapeseed-broad bean intercropping system in respect of producing seeds yield of rapeseed and defeat weeds.

MATERIALS AND METHODS

The experiment was performed in a completely blocks randomized design with four replications using replacement series in which broad bean and rapeseed were planted in different ratios of 100:0, 75:25, 50:50, 25:75 and 0:100 with a 20 bushes m^{-2} in 2014. Treatment of sole culture was used as controls. Each plot includes six furrows with 75 cm distance and 4 m length, that one cultivation line of each one of two crops is located on those. Plants were harvested from the soil surface at maturity and were oven dried at 75°C for 48 h, while total shoot biomass for each species being determined. Measurements included plant height, number of branches per plant, number of pod per plant, number grain per pod and plant grain yield in rapeseed. Relative Yield (RY), Relative Yield Total (RYT) and Relative Crowding Coefficient (RCC) were calculated. Relative Yield (RY) is a measure of the relative competitive ability of the two species. Large RY values indicate a high degree of competitiveness of one species relative to the other. Values of approximately one indicate that interspecific and intraspecific competition is equal. Values greater than one indicate that intraspecific competition is more than interspecific competition. Values less than one indicate that intraspecific competition is less than interspecific competition. The RY was calculated using the Eq. 1 (Ghadiri, 2005):

$$RY = \frac{Y_{mix}}{Y_{mon}} \qquad (1)$$

where, Y_{mix} and Y_{mon} are yields in mixture and monoculture. Relative Yield Total (RYT) describes how the species pair utilizes resources. Values of approximately one indicate that two species are competing for the same limiting resources. Values greater than one suggests that species are making demands on different resources, avoiding competition, or maintaining a symbiotic relationship. Values less than one imply mutual antagonism. When the RYT of a pair of species is approximately one, the combined yield of species in a mixture is predictable from species monocultures (Ghadiri, 2005). The RYT was calculated using the Eq. 2:

$$RYT = \sum_{i=1}^{n} RY \qquad (2)$$

Relative Crowding Coefficient (RCC) is a measure of competitiveness between the two species. Large RCC values indicate a high degree of competitiveness of one species relative to the other. The RCC was calculated using the Eq. 3 (Ghadiri, 2005):

$$RCC = \frac{YA_{mix}}{YB_{mix}} \Big/ \frac{YA_{mon}}{YB_{mon}} \qquad (3)$$

where, YA_{mix} and YB_{mix} are average yield per plant of A and of B grown in mixture, respectively, YA_{mon} and YB_{mon} are average yield per plant of A and B grown in mono culture, respectively (Ghadiri, 2005). Means were compared using Duncans, Multiple Range Test ($p<0.05$) using SAS 2002 software.

RESULTS AND DISCUSSION

Weed dry weight, density and diversity: Weeds dry weight showed significant difference in different densities of canola and bean intercropping comparing to sole culture (Table 1). The lowest weed dry weight was observed in ratio of 50 and 25 of rapeseed with 29 and 35 g m^{-2}, respectively and the highest was achieved in ratio of 100 and 75 of rapeseed with 58 and 54 g m^{-2}, respectively (Table 1). Liebman and Dyck (1993) reported that weed dry weight will decrease in

Table 1: Dry weight, diversity and density of weed in different ratios of rapeseed-broad bean plantation

Presence of rapeseed (%)	Weed dry weight (g m^{-2})	Weed diversity (plant m^{-2})	Weed density (plant m^{-2})
100	58^{a}	4.4^{a}	29^{a}
75	54^{a}	3.2^{ab}	27^{ab}
50	29^{c}	3.0^{b}	20^{c}
25	35^{c}	3.0^{b}	22^{c}
0	46^{b}	4.0^{ab}	23^{bc}

Means with same letter do not have statistically significant difference at 5% probability level intercropping treatments comparing to sole cropping. Morphological and capability of broad bean in competition with other crops showed most reasonable effects on reducing weed dry weights. Similarly, intercrop treatments such as wheat-canola and wheat-canola-pea tended to provide greater weed suppression compared with each component crop grown alone, indicating some kind of synergism among crops within intercrops with regard to weed suppression (Szumigalski and van Acker, 2005). Sole culture of canola exhibited higher weed dry weight and increase in bean densities resulted lower weed dry weight. The lower weed density in sole bean culture comparing to sole canola culture, might be because of the higher performance of bean in the competition with weed. High growth rate, faster canopy closer and covering soil surface for a long time might be good reasons for lower weed densities in the bean parts of the farm.

The highest and the lowest weed density were related to 100:0 and 50:50 ratios by 29 and 20 plants, respectively. Decrease in broad bean density significantly increased the number of weed (Table 1). Recently, it was reported that intercropping maize with legumes considerably reduced weed density in the intercrop compared with maize pure stand due to decrease in the available light for weeds in the maize legume intercrops, which led to a reduction of weed density and weed dry matter compared to sole crops (Bilalis *et al*., 2010). Similarly, finger millet (*Eleusine coracana*) intercropped with green leaf desmodium (*Desmodium intortum*) reduced *Striga hermonthica* counts in the intercrops than in the monocrops (Midega *et al*., 2010).

Diversity of weed species is varying form sole and intercropping culture (Table 1). Weed diversity significantly decreased in intercropping system and it exhibited that farming systems could affected dry weight, diversity and density of weeds in farm. The minimum weed species was found in 50:50 ratio. However, no significant difference was observed between the rapeseed attendance of 50 and 25%. In fact obstruction of light is the most important effect that could inhibit weed seed germination by a rapid occupation of the open space between the main crop rows and reducing weed seedling growth and development (Steinmaus *et al*., 2008).

Relative Yield (RY) and Relative Yield Total (RYT): The RY values indicate the relative competitive ability of the two species. In the replacement series experiment in order to determine the competitive response of rival species we use the relative yield measure of each species as well as total relative yield or relative productivity of land (Baumann *et al*., 2002; Bhatti *et al*., 2006). Hence, the higher value of the relative yields of each species tend to higher its competitive strength. Gaudet and Keddy (1988) studied the competitive capability of 88 grass species in vase experiments and concluded that the biologic yield is a proper characteristic for indicating the competitive strength of a plant. The results showed that the relative yield of rapeseed decreased in the density ratio of 25 and 50% compared to the same density of broad bean (Table1). In comparison, rapeseed in a lower or even equal density was more sensitive to competition than broad bean and hence it faced to sharp yield decrease. However, in the higher planting densities of 75% the relative yield of rapeseed increased and the value reached to 1.191 (Table 2). Regarding the higher values of broad bean compared to rapeseed's relative yield in higher density ratios of 50 and 75% it can be concluded that broad bean possesses a higher competitive strength, as a consequence was able to better use nutrition resources. The RYT was higher than 1 in all mixture ratios (Table 1). This yield advantage occurs when the component crops do not compete for the same ecological niches and the interspecific competition for a given resource is weaker than the intraspecific competition. Yield advantage occurs because growth resources such as light, water and nutrients are more completely absorbed and converted to crop biomass by the intercrop over time and space as a result of differences in competitive ability for growth resources between the component crops, which exploit the variation of the mixed crops in characteristics such as rates of canopy development, final canopy size, photosynthetic adaptation of canopies to irradiance conditions and root in-depth (Midmore, 1993; Morris and Garrity, 1993; Tsubo *et al*., 2001). Intercropping maize with cowpea has been reported to increase light interception in the intercrops, reduce water evaporation and improve conservation of the soil moisture compared with maize alone (Ghanbari *et al*., 2010).

Relative competition coefficient: Relative competition coefficient of rapeseed in density ratios of 25 and 50% was lower than that was observed in broad bean (Table 2), which means that broad bean possesses a higher competitive strength compared to rapeseed even in equal density ratios. The capability of the plant for taking up nutritious factors such as water, different elements and light has a significant role in increasing its competitive ability. Among these light is the most important factor for creating rivalry in farming ecosystems because it is an instantaneous resource which cannot be stored (Fernandez *et al*., 2002). So, rapid growth can be an important factor in increasing the competitive capability of a plant. In contrast, broad bean possess a higher altitude

Table 2: Relative yields and relative competition coefficient in different ratios of rapeseed broad bean plantation density

Rapeseed: broad bean	RY of rapeseed	RY of broad bean	TRY	RCC of rapeseed	RCC of broad bean
75:25	1.191	0.398	1.59	3.109	3.180
50:50	0.441	0.605	1.05	0.709	1.390
25:75	0.215	0.797	1.01	0.317	0.324

RY: Relative yield, TRY: Total relative yield, RCC: Relative crowding coefficient which in turn increases its capability to absorb light that cause to rapid growth and expanding its canopy in the higher density ratios.

Biological yield, branch number and plant height of rapeseed: The biological yield of rapeseed was significantly affected by the density (Table 3) as by increasing the density of broad bean the biomass of rapeseed was decreased. The dry weight reduction of rapeseed in ratio of 25:75 was more than 26% compared to the pure culture (100:0). The decrease in biological yield of rapeseed in competition with broad bean return to the rivalry in taking up nutrition elements, light and humidity (Rahimian and Shariati, 1998; Tingle *et al*., 2003; Ross and Van Acker, 2005; Soleimani *et al*., 2010). In the study of SafahaniLangerodi *et al.* (2007) the biological yield of rapeseed, hayola 401 in the mixed cultivation with crops decreased up to 61%. Mirshekari and Javanshir (2008) stated that season-long interference of crops cause to 40% reduction in biological yield of rapeseed.

A very similar changing pattern similar to that observed in biological yield found in plant height and number branches plant^{-1} (Table 4). Ghadiri (2005) using a similar replacement series experiment, reported that pinto beans (*Phaseolus vulgaris* L.) shoot and root dry matter decreased as the number of field bind weed (*Convolvulus arvensis* L.) plants per pot increased.

Yield and yield components of rapeseed

Number of pods per plant: Results showed that the effect of density ratios on pods plant^{-1} was significant ($p<0.01$) (Table 3). Broad bean density influenced maximum number pods plant^{-1}. The highest and lowest number of pods plant^{-1} were related to 100:0 (704 pods) and 25:75 (372 pods) ratios. Decrease in rapeseed density significantly decreased the number of pods plant^{-1} (Table 4). This might have been the result of decline in light interception by plant canopy. Therefore, initiation of constituent buds on secondary branches declined. The decrease in the number of secondary branches is the main cause of decline in pods plant^{-1}. Furthermore, the diminishing carbohydrate supply with exceeding competition among the plants at the flowering time is another reason (Eilkaee and Emam, 2003). This result was consistent with those of (Hosseini *et al*., 2006; Ozer, 2003). In order to maintain the equilibrium between generated materials of the source and amount of consumed materials in the reservoir, some of the flowers shed (SafahaniLangerodi *et al*., 2008) and decreasing number of flowers ultimately led to a decline in the number of pods in lower density of rapeseed. Blackshaw *et al.* (2000) reported the decrease of the pod number of rapeseed in competition with charlock.

Number of seeds per pod: Results revealed that the effect of density ratios on grain pods^{-1} was significant ($p<0.01$) (Table 3). The highest and lowest number of grains pods^{-1} were concerned to the ratios of 100:0 (34.2) and 25:75 (16.5). Increased broad bean density significantly decreased the number of rapeseed grains pods^{-1} (Table 4). This phenomenon due to the plant competition for absorbing environmental resources that resulting in reduction of photosynthetic materials and its transfer to rapeseed grains (Inayt-ur-Rahman *et al*., 2009; OzoniDavaji, 2006).

Weight of 1000 seeds: Results of the current experiment (Table 3) indicated that the effect of density ratios on 1000 grain weight were significant ($p<0.01$). The highest and lowest 1000-grains weight were related to the ratios of 100:0 (9.9 g) and 25:75 (7.9 g). Increased broad bean density significantly reduced the 1000-grains weight of rapeseed (Table 4), which indicated the intensity of competition and significant shortage of resources. Reduction of rapeseed grain weight in lower density can be attributed to the formation of smaller grains because of more limited access to environmental resources particularly light due to higher competition, declining production of photosynthetic materials and finally, transfer of less photosynthetic materials to the grains at grain filling period (Salehi, 2005; Abdolrahmani, 2003).

Table 3: Analysis of variance for the effects of different ratios of rapeseed-broad bean plantation on studied traits for rapeseed

S.O.V	df	Plant height	Branch No. plant^{-1}	Pod No. plant^{-1}	Grain No. pod^{-1}	1000 grain weight	Grain yield	Biological yield
Block	2	6.41^{ns}	0.143^{ns}	468.59^{ns}	0.591^{ns}	0.766^{ns}	6.11^{ns}	3.380^{ns}
Treatment	3	15165.10**	56.49**	17966.6**	33.980**	0.692**	165.80**	83.430**
Error	6	14.93	1.26	331.28	0.518	0.044	2.85	0.406
Total	11							
CV%		4.1	9.8	7.6	6.4	5.5	4.7	5.2

Ns: Non significant, **Significant at 1% probability level, df: Degree of freedom

Table 4: Means comparison of rapeseed studied traits in different ratios of rapeseed-broad bean plantation

Presence of rapeseed (%)	Plant height (cm)	Branch No. plant^{-1}	Pod No. plant^{-1}	Grain No. pod^{-1}	1000 grain weight (g)	Grain yield (g m^{-2})	Biological yield (g m^{-2})
100	250.0^{b}	22.6^{a}	704.2^{a}	34.2^{a}	9.9^{a}	44.1^{a}	81.4^{a}
75	279.0^{a}	37.6^{a}	798.0^{a}	29.6^{b}	9.7^{a}	37.1^{a}	80.1^{a}
50	195.7^{c}	21.8^{b}	469.5^{b}	23.4^{c}	8.1^{b}	16.2^{b}	60.7^{b}
25	160.8^{d}	15.5^{c}	372.5^{c}	16.5^{d}	7.9^{b}	8.9^{c}	59.1^{b}

Means with same letter do not have statistically significant difference at 5% probability level

Seed yield: Grain yield (Table 3) influenced markedly by density ratios ($p<0.01$). Comparing the averages showed that the maximum and minimum yields per square meter were at the density ratios of 100 and 25 by 44.1 and 8.9 g, respectively. Increase in broad bean ratios significantly decreased plant grain yield in manner that in ratio of 50:50 the reduction exceed by 63% in compare to pure culture (Table 4). The reason can be attributed to the reduction of yield components including, the number of pods plant^{-1}, number of grains pod^{-1} and 1000 grain weight. Rapeseed lower density decreased the yield of individual plant via reduction of pods number as well as the 1000 grain weight due to exceeded competition among plants for utilizing environmental resources. Aslani and Saeedipour (2015) showed that rapeseed was of a less competitive ability than wild mustard. Also, there was a significant negative correlation observed between wild mustard density and rapeseed yield components which implies that a high density of wild mustard can cause serious yield reduction in rapeseed. Amini *et al.* (2006) showed that the interference of the rye causes a decrease in the cumulative dry matter of wheat which in turn reduces the grain yield. In other researches the decrease in the grain yield of rapeseed in competition against crops is reported (Harker *et al*., 2001; SafahaniLangerodi *et al*., 2007; McMullan *et al*., 1994).

CONCLUSION

In general weed biomass, weed diversity and weed density were reduced in intercropping system compared to rapeseed and bean sole crops. Based on competition indices rapeseed was of a less competitive ability than broad bean. Also, there was a significant negative correlation observed between broad bean density and rapeseed yield components which implies that a high density of broad beanup to 25% can cause serious yield reduction in rapeseed.

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