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Effect of Plant Density and Mixing Ratio on Crop Yield in Sweet Corn/Mungbean Intercropping

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Abstract: In order to evaluate the ear and forage yield of sweet corn (*Zea mays* L. var. Saccarata) in pure stand and intercropped with mung bean (*Vigna radiata* L.), a field experiment was conducted at Varamin region on summer 2006. Experiment was carried out in a split plot design based on randomized complete blocks with 4 replications. Plant density with 3 levels [Low (D_1), Mean (D_2) and High (D_3) respecting 6, 8 and 10 m^{-2} for sweet corn, cultivar S.C.403 and 10, 20 and 30 m^{-2} for mung bean cultivar, Partow] was arranged in main plots and 5 mixing ratios [(P_1) = 0/100, (P_2) = 25/75, (P_3) = 50/50, (P_4) = 75/25, (P_5) = 100/0% for sweet corn/mung bean, respectively] were arranged in subplots. Quantitative attributes such as plant height, sucker numbers, LER, dry matter distribution in different plant organs were measured in sweet corn economical maturity. Furthermore the yield of cannable ear corn and yield components of sweet corn and mung bean were investigated. Results showed that plant density has not any significant effect on evaluated traits, while the effect of mixing ratio was significant ($p<0.01$). Therefore, the mixing ratio of 75/25 (sweet corn/mung bean) could be introduced as the superior mixing ratio; because of it's maximum rate of total sweet corn's biomass, forage yield, yield and yield components of ear corn in intercropping. Regarding to profitability indices of intercropping, the mixing ratio 75/25 (sweet corn/mung bean) in low density (D_1P_2) which showed the LER = 1.03 and 1.09 for total crop yield before ear harvesting and total forage yield after ear harvest respectively, was better than corn or mung bean monoculture.

Key words: Population, legum/cereal, intercropping systems, land equivalent ratio, mixing pattern, ear and forage yield

INTRODUCTION

In the interval between the two sequential cropping such as wheat-wheat, wheat-rape, etc., considering the time when the farm gets free of the previous crop and the time required for land preparation for the next crop in autumn, there is no sufficient time for cultivation of a grain plant as the main crop. From the other hand, very high temperature and prolonged summer of the arid and semi-arid regions like as varamin (30 km apart in SE of Tehran) justify the optimum use of water. Studying on cultivation of a plant with profitable and short growing season as well as high potentials for benefiting such a high heat and radiation of summer, would lead to increment of resources utilization efficiency.

Sweet corn (*Zea mays* L. var. Saccarata) is among tropical Gramineae, of which the growing period up to economic product harvest (ear in soft dough stage) is 75-80 days by average and which leaves a remarkable bulk of green biomass with high rate of protein, used as a byproduct for feeding purposes.

Multiple cropping is considered as one of the methods of environment-friendly and sustainable agriculture. In a tropical and subtropical region such as Iran, water is a limiting factor for planting date, which influence crop yields, intercropping is one of the strategies for optimum resources utilization efficiency and realization of objectives of sustainable agriculture (Vandrmire, 1989). Intercropping, including corn and bean which was popular in Mexico during 900 to 1500 BC (Francis, 1982), causes the enhancement of potential yield. In this case, according to plant diversity principle in farm, the grounds are prepared for increment of production, maintenance of soil fertility, erosion control and altogether optimum utilization of the resources (Mazaheri, 1998).

In many experiments of intercropping, in which the components are composed of one species of legumes and one species of cereals the yield of intercropping shows advantage over that of the sole cropping (Morris and Garrity, 1993). In this regard, such instances as intercropping of soybean/corn (Elomre and Jackobs,

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1986), corn/cowpea (Mandhal *et al*., 1996), corn/garden bean (Atri *et al*., 2000), can be mentioned.

The yield in intercropping systems depends on selection of compatible genotypes with suitable characters for establishment of a minimum competition and maximum assistance as well as application of appropriate inputs and farm operations (such as crop density, mixing ratio and intercropping pattern) (Mutungamiri *et al*., 2001). Mazaheri (1998) believes that intercropping may be useful when the crops have the roots of different depths; from the other hand, the stem length and plant growth pattern, play role in competition of two species for light. If two plants are similar with respect to stem length and growth manner, such issues as shading and competition for light would be effective on their yield. Inter specific variation in intercropping prevents the probable yield loss through reducing the pests and diseases as well as asphyxiating the weeds (Hosseini and Kolar, 1988).

In corn/soybean intercropping, the highest yield is resulted from a mixing ratio of 25% corn and 75% soybean (Pookpakdi, 1985, quoted by Danaeifar *et al*., 2001). Similarly, Mazaheri (1998), having mixed 75% corn with 25% bean, produced 16% more yield in comparison with sole cropping of these two species. According to findings of Zand and Ghafari Khaligh (2002), mixing ratio of 50:50 (1 to 1) for cowpea and grain sorghum showed 19% profitability in comparison with their sole cropping. Having estimated the aggresivity index in intercropping treatments, they stated that cowpea was the dominant species and has used the environmental conditions more efficiently.

Barzegari *et al*. (2004) expressed that intercropped pop corn and cowpea, leaved very significant differences in yield components of pop corn and bean. According to LER for grain yield, intercropping showed superiority over sole cropping.

Rahimi *et al*. (2004), having compared the three different ratios of intercropping of corn and soybean with their sole cropping, determined that the maximum yields are, respectively for treatments related to 50% intercropping of both crops and then 25% corn and 75% soybean. Also, they indicated that reducing the number of corn rows, the length of ear, number of ears in each plant, kernel number per ear, soybean pod number, 1000 weight of grain soybeans and crude protein percent of soybean increased, probably as a result of less shading and dominance of corn.

According to Danaeifar *et al*. (2001), high plant density, increased the dry matter in both pure stand and intercropping.

In a research on the effect of density and planting arrangement on qualitative and quantitative yield of forages in intercropping of Egypt clover and barley forage, Shahrivar *et al*. (1996) stated that in all intercropping cases, with enhancement of density, the dry matter yield increases and the maximum yield of dry matter is related to 50:50 (barley/clover) intercropping in high density that has caused equal to 6.06% overproduction in comparison with maximum yield of sole cropping. In addition, with the rise of density, LER increases, in such a manner that the maximum LER was reached in high density and 50:50 (barley/clover) intercropping. Also the highest rates of crude protein were reached in this ratio. Since researches made on different resources have put emphasis on profitability of intercropping of one legume and one cereal, the general objectives of this study are considered as evaluation of the impact of mung bean (*Vigna radiata* L.)/Sweet corn mixing ratios and plant density on the yield of sweet corn as the main crop.

MATERIALS AND METHODS

Experiment was carried out in summer 2006 in an agricultural area located in Varamin region (30 km apart from South East of Tehran, 35°20' N, 51°31' E, 1050 masl).

Soil texture was determined as clay loam with pH = 7.65 and OC = 0.71%.

The farm had been under wheat crop the previous year. Therefore, preparation works including tillage, basic fertilization, disc harrow, leveler, making ridges and furrows, etc., were fulfilled after wheat harvest in early July. Experiment was carried out in a split plot design based on randomized complete blocks with 4 replications. Plant density with 3 levels (6, 8 and 10 plant m^{-2} for sweet corn, cultivar S.C.403 and 10, 20 and 30 plant m^{-2} for mung bean cultivar, Partow) were arranged in main plots and 5 mixing ratios (0:100, 25:75, 50:50, 75:25, 100:0 for Mung bean/Sweet corn) were arranged in subplots. Seeds of the two crops were simultaneously planted on July 28, 2006. Each experimental unit was composed of 6 cropping rows, each 6.5 m long, 0.75 m apart. Within each plot, alternative cropping lines 2, 3, 4 and 5 were allocated to sweet corn or mung bean with intended mixing ratios and in marginal lines of each experimental unit (lines 1 and 6) sweet corn was planted.

All measures of crop management were taken, including distribution of top-dressing, weeding out, pests and probable diseases control and irrigation with common method of the region, if necessary. Soil fertilization works were performed in two stages on

September 6 and October 3, on the basis of needs of crops for nitrogen as was shown by results of soil analysis and in the form of row banding. Harvest of sweet corn was done on October 31 in soft dough stage (economic maturation). In this stage, sampling was made on four middle lines with a length of 4 m, indeed of total fresh weight of biomass in harvest area (9.6 m^{-2}), 10 plants of sweet corn and 10 plants of mung bean were prepared as explants, to determine oven dried weight. Some morphological parameters such as length of ear, number of suckers per plant, diameter of corn stem, height of corn plant and height of mung bean plant, were examined before sampling.

Also yield components of both sweet corn and mung bean were determined.

Statistical analysis of experimental data was done using SAS program using (PROC ANOVA). Then the means of traits under study were compared through Duncans multiple range test.

RESULTS AND DISCUSSION

Corn biomass (biologic yield): Results of data variance analysis indicated that the total dry matter, forage yield after ear harvest as well as dry matter of different organs of sweet corn (leaves, stem, ear) have not been impacted by the plant density (Table 1). The mixing ratio of the two components crop, however, has left a significant effect ($p \leq 0.01$) on the mentioned traits. Although the interaction of these traits was not significant, Pillai *et al.* (1990), having reviewed the ecologic benefits of forage corn/cowpea intercropping, stated that such an intercropping has increased significantly the yield of green forage and dry matter. Means comparison indicates that total dry matter in medium density D_2 (8 plants m^{-2}) has shown the highest yield and in such a density of the dry matter distributed in different plant organs, the ear has had more share in comparison with other organs (Table 2) Francis *et al.* (1982) explained that corn in the density of about 6 plant m^{-2} would show the highest yield. In this experiment with the rise of density, the dry matter distributed between leaf and stem has increased, but the ear yield has declined (Table 2) because in high density the lower leaves, being placed under the shade, usually show the higher rates of respiration than those of photosynthesis and act as a parasite for the plant and especially for the upper leaves.

In sweet corn, just like most of other agricultural species, inflow and utilization of soluble carbohydrates together with amino acids, as a source of reduced nitrogen, is necessary for vegetative and reproductive growth, therefore, in this stage of plant growth, partitioning of assimilates to the ear is more than the other organs that has caused increment of dry matter in the ear. In this stage, the carbohydrates required for filling the kernel are originated from current photosynthesis and transition from temporary sources of stems, leaves, cob and husk. But the change in density results in change in the yield.

In some states of plant density, the yield will be turned from positive state to negative state; in such a case, competition and assistance make impressions

Table 1: Analysis of variance of Mean squares of sweet corn biomass (final harvest)

SOV	df	Husk dry weight	Cob dry weight	Kernel dry weight	Ear dry weight	Steam dry weight	Leaf dry weight	Forage dry weight (after ear removing)	Total dry matter
Replication	3	286.0304**	877.6682**	14456.0049**	29330.809**	49291.4656**	2658.8902**	86901.848**	172256.223**
Plant density	2	104.3299	66.8159	1310.188	2908.735	1577.374	348.0353	1872.389	5479.663
Error a	6	71.5817	39.3569	2676.325	3907.737	3855.395	207.5355	6863.358	4210.634
Mixing ratio	4	3591.2848**	9819.2096**	129769.6242**	277337.534**	235659.1009**	24660.5388**	434134.055**	1431660.408**
Interaction effect	8	44.8271	188.5004*	810.5502	1621.261	2709.959	31.7232	3556.11	4903.104
Error	36	44.2969	66.8995	1280.711	2173.071	2240.286	182.0586	3714.955	8514.179

*and **: Significant at the 5 and 1% levels of probability, respectively

Table 2: Means comparison of sweet corn biomass in soft dough stage (final harvest) affected by plant density and mixing ratio

Considered factor	Husk dry weight ($g\ m^{-2}$)	Cob dry weight ($g\ m^{-2}$)	Kernel dry weight ($g\ m^{-2}$)	Ear dry weight ($g\ m^{-2}$)	Steam dry weight ($g\ m^{-2}$)	Leaf dry weight ($g\ m^{-2}$)	Forage dry weight (after ear removing) ($g\ m^{-2}$)	Total dry matter ($g\ m^{-2}$)
Plant density								
Low (D_1)	28.573a	46.211a	155.84a	231.99a	182.93a	53.579b	250.27a	469.09a
Mean (D_2)	28.044a	43.627a	167.05a	244.03a	206.01a	63.375b	276.12a	520.15a
High (D_3)	23.219a	41.130a	138.35a	202.70a	211.30a	72.520a	283.82a	470.62a
Mixing ratio M/S								
P_1 100/0	42.699a	76.191a	277.43a	404.40a	376.18a	131.067a	516.09a	917.12a
P_2 75/25	41.200a	63.193b	213.22b	317.09b	291.60b	95.584b	387.19b	690.91b
P_3 50/50	34.988b	55.190c	192.89b	283.07b	208.39c	67.232c	275.62c	558.70c
P_4 25/75	19.694c	32.594d	107.78c	160.07c	118.04d	43.964d	162.00d	322.07d
P_5 0/100	0.00d	0.00e	0.00e	0.00d	0.00e	0.000e	0.00e	0.00e

Means with the same letter(s) in each column are not significantly different at 5% probability level using Duncan's multiple range test simultaneously. This state is seen in medium density (D_2), in such a manner that with the rise of density, we would witness the yield loss. In other words, it can be understood that in medium density, corn has used the environmental conditions better and by the rise of density as a result of intensification of intraspecies competition, the increment of biomass yield has stopped and/or even has encountered the reduction of dry weight.

As to dry weight of fodder corn after harvest of ear, it is seen that with the rise of plant density, forage dry matter has shown an upward trend as a result of plant density increasing as well as increment of stem and leaf dry matter. Therefore, a positive relation between plant density and dry matter accumulation in sweet corn forage could be expected.

As can be shown in Table 2, the highest dry matter of sweet corn has reached in sole cropping and as a result of reduction of corn portion, sweet corn dry matter decreased and such reduction of yield has not been changed equally and has been in such a manner that the total sweet corn dry matter has shown 24 and 19% reduction in comparison with control treatment, respectively in 75/25 and 50/50 sweet corn/mung bean treatments. Also in 25/75 sweet corn/mung bean intercropping, we see a 21% loss in ear dry matter, but in 50/50 sweet corn/mung bean, only a 10% yield loss has occurred. That is to say that the rate of ear dry matter has been reduced by reduction of ear portion at intercropped treatment.

Tripathi *et al*. (1987) studied on forage yield in sole cropping and legume/cereal intercropping in summer, observed that in sole cropping, sorghum (Pioneer 988 cultivar) and corn (African tall cultivar) produced significantly more fresh forage and dry matter in comparison with other treatments.

Having examined the intercropping of chick pea and barley for forage production, Daryaei *et al*. (2006) concluded that chick pea forage yield was influenced by mixing ratio ($p\leq 0.01$) and chick pea pure stand showed the highest forage yield. According to the records of Danaeifar *et al*. (2001), with the rise of density, the dry matter produced in both sole cropping and intercropping increased. They high plant density particularly as to forage crops, creates a suitable microclimate and results in the rise of total dry matter yield. Similarly Shahrivar *et al*. (1996) stated that in all cases of barley/clover intercropping, with the rise of density, dry matter yield has increased and the highest yield of dry matter was related to 50/50 mixing ratio in high density.

Ear yield: Plant density has caused no significant difference on ear, kernel, cob and husk dry weight. The impact of mixing ratio, however, on these traits was so significant ($p\leq 0.01$) and interaction of density and mixing ratio has resulted in a significant difference only in cob dry weight (Table 1).

As indicated by the table of comparison of means of traits (Table 2), the highest rate of kernel dry matter is in density D_2 (mean), but as to cob and husk dry weight, has decreased with the rise of dry matter density. Although, there is no statistically significant difference between the rates achieved, however, the fluctuation of yield is resulting from such issues as shading of plants and competition in high densities and such an effect is related to reduction of sun radiations to lower parts of plants in high densities. Also it can be seen that with the rise of corn portion in experimental plots, dry matter increases in such a manner that the corn sole cropping has had the highest dry matter in kernel and with increment of mung bean portion, corn yield has decreased due to interspecies competition.

Relative Crowding Coefficient (RCC): This index determines the rate of competition between two species, which has been intercropped through replacement series. Treatments with RCC<1 are interpreted as non-profitability of intercropping in comparison with sole cropping. Such conditions can be seen for total biomass yield both before and after ear harvest, but the mixing ratio 75/25 (sweet corn/mung bean) in low density (D_1P_2) and mean density (D_2P_2), respectively with RCC of 1.20 and 1.11 and also this same density and mixing ratio of 25/75 (sweet corn/mung bean) with RCC = 1.43 are considered as the most profitable intercropping states with respect to total dry matter yield before harvest.

In general, in sweet corn/mung bean intercropping, mung bean is always the recessive species, in such a manner that in most of the cases, its RCC (K_m) for the yield both before and after corn ear harvest is less than RCC for sweet corn (K_s).

Considering the morphological difference and physiological properties of these two species, appearance of such a result is expectable because sweet corn, as a C_4 crop possesses a relatively high growing rate and has overcome the second component of intercropping (mung bean) in utilizing the sources especially the light. More RCC of sweet corn (K_s which is more than 1) in comparison with that of mung bean, supports this conclusion.

On the basis of Mazaheri (1993) report, profitability in intercropping is resulted when the partners are different from each other with respect to growth form and manner and absorption rate of inputs (light, water and food), in

Table 3: Land equivalent ratio for total biomass and forage yield in intercropping of mungbean and sweet corn

	Total crop yield before of ear's harvest			Total forage yield after of ear's harvest		
Treatments	RYs[1]	RYm[2]	LER[3]	RYs	RYm	LER
D_1P_2	0.827	0.200	1.03	0.887	0.200	1.09
D_1P_3	0.579	0.363	0.94	0.547	0.363	0.91
D_1P_4	0.355	0.617	0.97	0.315	0.617	0.93
D_2P_2	0.748	0.272	1.02	0.704	0.272	0.98
D_2P_3	0.578	0.348	0.93	0.475	0.348	0.82
D_2P_4	0.375	0.704	1.08	0.309	0.704	1.01
D_3P_2	0.715	0.119	0.83	0.761	0.119	0.88
D_3P_3	0.658	0.268	0.93	0.583	0.268	0.85
D_3P_4	0.315	0.472	0.79	0.317	0.472	0.79

$(D_1)^1$, $(D_2)^2$ $(D_3)^3$; (P_1)*, (P_2)**, (P_3)***, (P_4)****, (P_5)*****, [1]Relative Yield of sweet corn; [2]Relative Yield of mung bean; [3]Land Equivalent Ratio; [1]Low plant density; [2]Mean plant density; [3]High plant density; *(100/0), **(75/25); ***(50/50); ****(25/75); *****(0/100); percents for sweet corn/mung bean, respectively

such a case, interspecies competition will be less than intraspecific competition and with reduction of competition, profitability of intercropping is guaranteed. Should after ear harvest, the remainder of biomass is considered as forage, the superior treatment can be selected with more accuracy in RCC rates for experiment units. In this experiment, D_1P_2 with RCC = 1.98 was the best intercropping, treatment.

Land Equivalent Ratio (LER): The highest LER for total yield before ear harvest was reached in D_2P_4 equal to 1.08; followed by D_1P_2 with LER = 1.03 (Table 3). On such a basis, total biomass dry matter yield, resulting from intercropping in mentioned treatment, has respectively shown 8 and 3% increment in comparison with sole cropping. Meanwhile, in evaluation of dry biomass yield after ear harvest, it is seen that D_1P_2 treatment, leaving LER equal to 1.09 and 9% yield rise in comparison with sole cropping, followed by D_2P_4 with LER = 1.01.

For the purpose of reviewing the forage production in sorghum/cowpea intercropping. Sharifi *et al*. (2006) reported the highest LER (1.26) in 75/25 (sorghum/cowpea) mixing ratio.

Also Daryaei *et al*. (2006), having intercropped black chick pea and barley for forage production through dry-farming, recorded the highest LER as 1.25 in a dense population of intercropped chick pea/barley.

In many of similar researches which have been performed as to intercropping of corn with such legumes as cowpea (Ennin *et al*., 2001), bean (Raja and Reddy, 1990; Francis *et al*., 1982; Hikam *et al*., 1992; Bigonah *et al*., 1996, cowpea (Barzegari *et al*., 2004), soybean (Carrutherset *et al*., 2000; Danaeifar *et al*., 2001), intercropping has always an advantage over sole cropping, in such a manner that in the mentioned experiments, LER was always more than unit.

According to Mazaheri (1993, 1998), difference in height and growth periods of two plants are among the main reasons for advantage of intercropping of such plants in comparison with sole cropping of each of them. In this regard, ecological niche for the purpose of absorption of sources and establishment of competition reduction mechanism can be discussed as a scientific justification for profitability of sweet corn/mung bean intercropping in comparison with their sole cropping.

CONCLUSION

As the conclusion of different sections of this study and considering the main objective of the experiment, mixing ratio of 25/75 (mung bean/sweet corn) is introduced as the superior mixing ratio, because this treatment produced the highest rate of total sweet corn biomass. It is worth mentioning that the highest rate of forage sweet corn yield and yield components of ear was achieved in above mentioned treatment.

Intercropping profitability indices support this claim, because mixing ratio of 25/75 (mung bean/sweet corn) in low density (D_1P_2), leaving the LER = 1.03 and =1.09 for total biomass yield before ear harvest and total dry forage yield after harvest, have stood at the first place in comparison with sole cropping. In reviewing the rate of competition index, it can be stated that with the mentioned mixing ratio in low densities, sweet corn which had shown the highest LER, left the least competition index of 0.83 and 0.5, for total biomass and forage yield, respectively.

In order to increasing the green chop forage yield of sweet corn as a by product in summer cropping in such a warm condition, mung bean/sweet corn intercropping with 25/75 mixing ratio in severely recommended.

In this case we can produce enough fresh ear yield as vegetable for us and additional green forage for our livestoks.

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