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An evaluation of yield in "intercropping of maize and potato"

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Abstract

To find out how maize and potato can grow and develop in an intercropping system rather than each grown alone in a sole cropping system the following factorial experiment was performend in the frame-work of a randomized complete block three replications in the experimental farm of the faculty of agriculture, Zanjan University in year 2004. Different potato to maize ratios of (1:0), i.e. sole potato;(3:1) meaning 75% potato plus 25% maize; (1:1), that is half and half of each crop; 25 percent potato together with maize of 75% (1:3); and finally sole cropping of maize (0:1) were employed. Two plant population treatments of 3.8 and 5.3 plants/ m^2 were assigned to each crop. There was an increase observed in the radiation absorption and in Leaf Area Index (LAI) with an increase in plant density from 3.8 to 5.3 plant per square meter. Maximum potato yield (20390 kg/ha) was obtained from 3:1 crop ratio and maximum yield of maize (8898 kg/ha) from the 1:1 ratio of intercropping system. In the case of potato the new cropping system (intercropping) there were significant ($\alpha = 0.05$) observed in yield, mean number of branches per plant, as well as in mean weight of potato tubers. In maize, the cropping system revealed a significant effect on yield, mean number of ears per plant as well as on mean number of seeds per year. Land Equivalent Ratio (LER) was shown to be more than one for all the treatments indicating more profitability and superiority of intercropping to sole cropping system. The highest LER for either one of the crops in intercropping system was 1.58. This was obtained for potato in the 3:1 ratio treatment while for maize it was obtained for the treatment of 1:1 ratio.

Key Words: Sole cropping; Intercropping; Land Equivalent Ratio (LER); Dominance; Substitution

1. Introduction

So for most research work in agriculture has been done in the context of sole cropping, while little relative attention is being paid to such other systems as intercropping. Intercropping is among traditional agricultural methods of long precedence. This method of agriculture is economical in areas where all agricultural inputs other than labor are in scarcity. It is tried in these areas to make the maximum use of the growing environmental potentials via either intercropping or subsequent cultivation of two or more crops that vary in time of plantation and harvesting as well as in manner of growth and development. In total, interspecies completion among plants is more pronounced than that in interspecies, and this is because in t he latter case the intercropped plants vary in their growth requirements (due to the difference in morphology root depth, as well as in peak irrigation period, etc. In the choice of a proper combination of different species of field crops, they can be complementary to each other as regards better use of the needed resources of light, water and plant nutrients (if intercropped).

Some research workers are of the opinion that plants intended to be employed in intercropping do not necessarily have to be of the same planting and harvest date. Plants, the growing periods of which are even partly coincident with each other could have their place in a mixed or intercropping system. Research in the process and stages of plant growth can provide valuable information needed regarding this type of crop production. It has

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been demonstrated that if plants vary in their stages of development during their growth period are in less competence with each other and therefore make better use of available resources resulting in higher yield. Not all crops if intercropped could result in extra yields. That largely depends upon compatibility as far as plants, physiology and morphology are concerned.

In spite of the vast extent in development of sole cropping, still in some countries, intercropping is dominant, some reasons for which could be mentioned as: extra yield with little or no increase in inputs; stability in production during various years and growing seasons, decrease in the incidence of pests and diseases; a more naturally occurring weed control; prevailance of a more suitable microclimate; diminishing trend of losses arising from natural environmental disasters such as cold, drought; and finally the positive aspect of interaction that exists between or among plants.

Sharaiha et. al. (2004) in an evaluation of different interactions of potato, beans, and maize in an intercropping system reported the two cultivars Agrico and Sponta of potato, in case intercropped along with maize and beans, would yield more in comparison with sole cropping. In the case of Alaska cultivar, if intercropped with beans the yield was 17-32% more than if planted in a sole cropping system. This is while its intercropping with Maize yielded less than sole cropping to an extent of 61%. This significant decrease in yield was attributed to leaf area value and light interception. Maize yield when intercropped with beans or potato, no matter what the cultivar (s), increased significantly. Land Equivalent Ratio (LER) also indicated a conspicuous superiority to sole cropping system.

Sharaiha, and Battikhi (1999) in a study of theirs, demonstrated the profitability of change in microclimate and superiority of yield in maize and potato row-intercropping in patterns of 1:2 and 2:2. They reported increase in maize and potato yield particularly in 2:2 ratio intercropping. Water use efficiency was significantly increased when compared with sole (single) cropping. Increase in maize yield is mostly related to the highe values of microclimatical factors, as a result of which (in all experimental combinations) intercropping ends up with more efficacy than intercropping.

Sharaiha et al. (1989) reported a decrease in bean Alternaria intensity when intercropped with maize. A similar decrease in potato blight was observed when intercropped with beans. Maximum decrease in maize rust was observed when it was intercropped with beans. An increase in yield of all the three crops in intercropping was observed as compared with sole cropping. Listeria and Merpong (1980) in a study of the effect of different combinations of intercropping on crop rotation on high land areas reported an increase in income (during a six rotation period) in intercropping of 3 crops with a one row of each arrangement. Highest gains were respectively obtained in the “potato, leek, and carrot”; “white cabbage, white raddish, and beans”; and “sweet corn, leek, and beans” successions. Evangelio and Rosario (1981) in a study of the effect of different cropping systems of sweet corn and sweet potato on their growth and yields reported 75 and 66% increase in their respective yields in intercropping as compared with their sole cropping system.

Amin Amini Behbahani et al. (1997) in a study of plant population in sole and intercropping of potato and maize reported the superiority of mixed to sole cropping in the forms (treatments and patterns). The final yield of good quality and marketable tuber was highly and significantly dependent upon planting patterns. The highest LER was obtained from corn at the rate of 40 percent corn along with 60% potato. Competence between the two crops was observed to be less in intercropping than in the sole cropping system.

2. Materials and Methods

The study was carried out in 2003 on the research farm of the faculty of agriculture, University of Zanjan. Zanjan is mountainous, with a cold arid climate of about 293.5 mm of rainfall. It is located at an evaluation of 1634 m (a.s.l.), 36°, 37′ north latitude of the semi-arid regions of the world. The soil was clay in texture, with an Electrical Conductivity (EC) of 2.27 mmhos/cm, and PH of 7.9.

The experimental design was a factorial one of randomized complete block of three replications with the following three factors and while substitution method being used in the mixed design.

Factor A= planting pattern
a1=0:1, sole cropping, potato
a2=1:3, maize: potato
a3=1:1, maize: potato
a4=1:3, maize: potato
a5=0:1, maize, sole cropping

Factor B= potato, plant population
b1=5.3 plant/m^2
b2= 3.8 plant/m^2

Factor C= maize plant population
c1= 5.3 plant/m^2
c2= 3.8 plant/m^2

Following land preparation, beds and furrows were made at distances of 75 cm. Row planting of potato at distances of 25 and 35 cm in between plants was carried out on the basis of the design map on April 19. 2004. Sole and intercropping (six rows) was performed according to the predetermined number of treatments and planting pattern. Agria variety of potatoes from Netherlands was the chosen variety.

Maize (single cross 301 variety) was planted on May 1^{st} 2004, while observing along with following the above mentioned conditions. Post planting protection measures observed included the application of Nitrogen fertilizer in the form of top dressing and in equal amounts for either one of the crops. Different phonological stages were recorded for both crops from planting to harvest.

Following full maturity, the crops maize and potato were respectively harvested on Sep. 11^{th} and 25^{th} 2004. In order to eliminate the marginal effect, one crop row was left out from each side of the experimental plots. Half a meter distance from top and bottom of the remaining four rows were also eliminated to further observe the elimination of the erroneous marginal effects. Yield for each crop was found out in proportion to the area (ratio) in each treatment. The measured yield components were: number of plants per unit area; mean number of ears per plant; mean number of kernels per ear; as well as 1000 kernel weight for maize. In the case of potato, the componentsof yield were: number of plants per unit area; number of branches per plant, mean number of tubers per branch, along with the average weight of each tuber. LER (Land Equivalent Ratio) was employed for an evaluation of mixed cropping (intercropping), while MSTAT-C used an analysis of data. Duncan multiple range test was employed for a comparison of means, while EXCEL software for sketching curves and graphs.

3. Results

The different phonological growth and development stages of maize and potato (Zanjan environmental conditions) are reflected in table 1.

The results of analysis of variance of the different treatments for potato traits are referred to in table 2 and those for maize in table 3. Maximum potato yield (20390 kg) was obtain from the treatment of 75% potato and maize (25%) as reflected in table 4. The effect of planting pattern (Factor A) was significant on yield, mean number of branches per plant, and mean tuber weight ($P<0.05$), but it was not significant as regards number of tubers per branch (table2).

The effect of factor B (potato plant population) on yield was significant ($P<0.05$), but it did not have any significant effect on yield components (table2). The effect of factor C (maize plant population) on potato yield, mean number of tubers per branch, and mean weight of potato tubers were significant at 5 percent level of significance, but it did not show any significant effect on the number of branches per plant (table 2). The effect of AB, AC, BC and ABC on potato yield and yield components was not significant. BC was significantly ($P<0.05$) effective on potato number of branches per plant (table 2).

The effect of Factor A (planting pattern) was not significant on maize yield, mean number of ears per plant while being significant ($P<0.05$) on 1000 kernel weight (table3).

The effect of Factor B (potato) on maize yield and maize yield components was not significant. Factor C (maize plant population) effect was not significant on maize yield and number of ears per plant, but was significant ($P<0.05$), on the traits of: mean number of kernels per ear, and one thousand kernel weight (table 3).

No significance was observed in the effect of AC and ABC on Maize yield and yield components. No significant effect of AB and BC on either maize yield or 1000 kernel weight was observed. But mean number of kernels per ear was affected by BC interaction ($P<0.05$). Also the effect of AB interaction on the mean number of ears per plant ($P<0.05$) was observed as significant (table 3).

Maximum maize yield (8898 kg/ha) was obtained from the 50:50 maize-potato ratio (a3b1c1), namely from 1:1 ratio. Plantt population in this finding was 5.3 plant per m^2 (table4).

For an evaluation of the mixed plantation of these two crops the indicator Land Equivalent Ratio (LER) was also employed. Maximum LER=1.58 was obtained for any of the two treatments of 75:25 and 50:50 potato: maize, namely (a2b1c1), (a3b1c1) treatments standing for 3:1 and 1:1 crop ratios. It must be remembered that maximum yield in either crop of potato or maize were obtained in 75:25 potato-maize (a2b1c1) and 50:50 (a3b1c1) treatments (table 4).

Table1. Maize and potato phenological stages in Zanjan environmental conditions

Phenological stages	Days after planting	
	Maize	Potato
Germination	7-9	10-13
Emergence	11-14	17-20
Flowering	-----	43-45
Tubering	-----	45-48
Tassel emergence	45-50	-----
Cob emergence	69-71	-----
Ripening	116-125	145-160

Table 2. Analysis of Variance for yield and yield components of Potato in Intercropping

Sources of Variations	Degrees of Freedom	Mean squares			
		Yield	Mean number of branches/plant	Mean number of tubers/branch	Mean tuber weight
Replication	2	41118537.06	0.166	0.16	5785.57
A	3	34198262.94*	0.19*	0.22	2179.99*
B	1	61830260.08*	0.00	0.05	1298.75
AB	3	4831926.91	0.02	0.03	748.51
C	1	32204718.52*	0.14	0.68*	6695.32
AC	3	12908377.07	0.02	0.16	1151.19
BC	1	1734700.52	0.29*	0.16	1855.55
ABC	3	3513976.52	0.03	0.05	959.09
Error	30	7230978.46	0.06	0.08	626.66
		C.V=16.70%	C.V=10.15%	C.V=18.25%	C.V=17.94%

* Significant at 0.05 probability level

Table 3. Analysis of Variance for the Yield Components of Maize in Intercropping

Sources of Variations	Degrees of Freedom	Mean square			
		Yield	Numbers mean of branch/plant	Numbers mean of tuber/branch	Mean of tuber weight
Replication	2	308012.58	0.003	3432.97	413.98
A	3	3420040.52	0.003	6372.08	2570.40
B	1	3340130.08	0.009	202.13	798.70
AB	3	547328.75	0.020*	4696.18	1446.34
C	1	5126054.08	0.000	85505.62*	12650.96
AC	3	2785188.08	0.002	20591.48	912.78
BC	1	1438668.75	0.003	28572.39	210.84
ABC	3	586460.30	0.006	10610.25	103.11
Error	30	12409760.49	0.004	5906.33	579.28
		C.V=15.7%	C.V=6.25%	C.V=12.65%	C.V=9.29%

* Significant at the 0.05 probability level

Table 4. Land Equivalent Ratio (LER) for different treatments of Potato and Maize in Intercropping

Treatments	Potato Yield (kg/ha)		Maize Yield (kg/ha)		LER
	Slope crop	Inter crop	Slope crop	Inter crop	
a_1b_1					
a_2b_2	24338				
$A_2b_1c_1$		20390		6666	1.58
$A_2b_1c_2$		19210		6941	1.57
$A_2b_2c_1$		15730		5236	1.23
$A_2b_2c_2$		16460		6443	1.4
$A_3b_1c_1$		14000		8898	1.58
$A_3b_1c_2$		19410		6864	1.57
$A_3b_2c_1$		13050		7211	1.35
$A_3b_2c_2$		15520		7019	1.42
$A_4b_1c_1$		12440		8074	1.42
$A_4b_1c_2$		16300		6645	1.41
$A_4b_2c_1$		12840		7696	1.39
$A_4b_2c_2$		14670		6263	1.31
A_5c_1			8777		
A_5c_2					

The standard LER formula in which maximum yield (in single cropping) and yield (in intercropping) values (as follows) are used was applied in the calculations.

$$LER = \frac{CropAyield(intercropping)}{MaximumcropAyield(solecropping)} + \frac{CropByield(intercropping)}{MaximumcropByield(solecropping)}$$

Since substitution method was used in the intercropping of the two products, dominances in the mixture of potato and maize in the four plant populations and planting patterns were determined on the basis of the aforementioned formula.

In planting pattern of 3:1 (75% potato and 25% maize) potato was the dominant crop in all plant population treatments.

As for planting pattern of 1:1 (50% potato and 50% maize), except for a3b1c1 treatments in which plant population for potato was 5.3 while for maize 3.8 plants per square meter (no competence between the two crops as a result) , for the remaining plant populations, maize was the dominant and potato the inferior crop.

In 1:3 planting pattern (potato 25% and maize 75%) maize was the dominant while potato the less dominating crop.

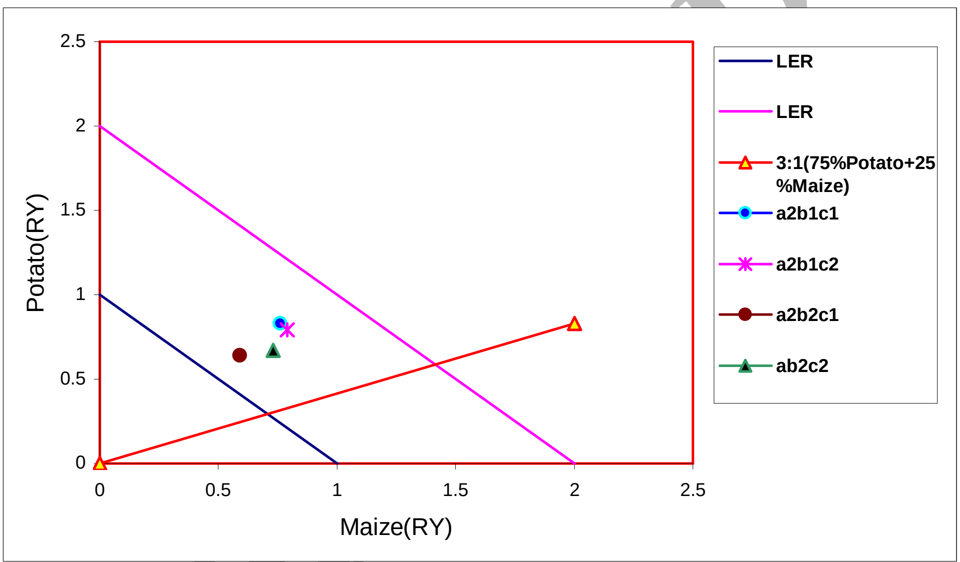

Fig.1. Land equivalent ratio (LER) and Aggresivity in four different density of Maize-Potato intercropping

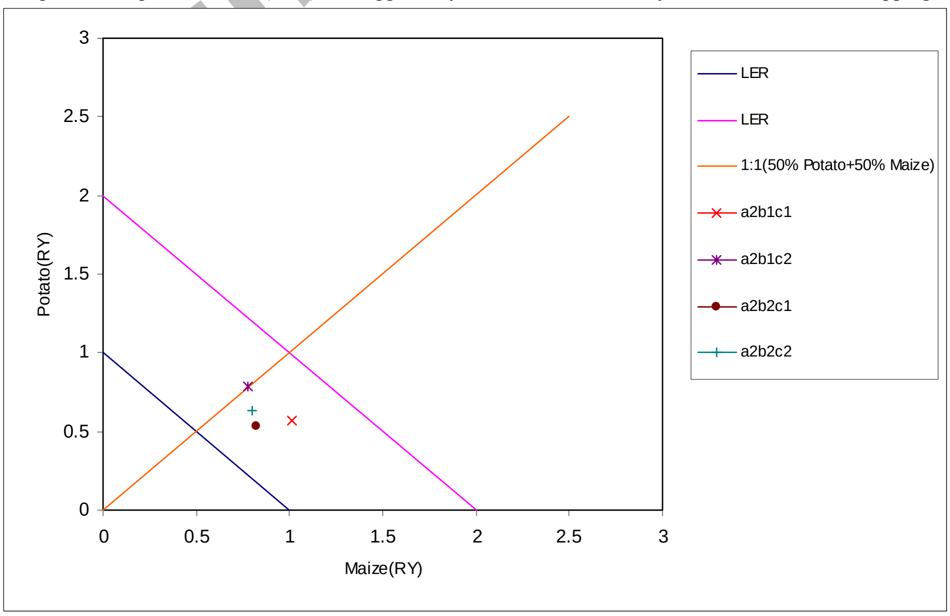

Fig.2. Land equivalent ratio (LER) and Aggresivity in four different density of Maize-Potato intercropping

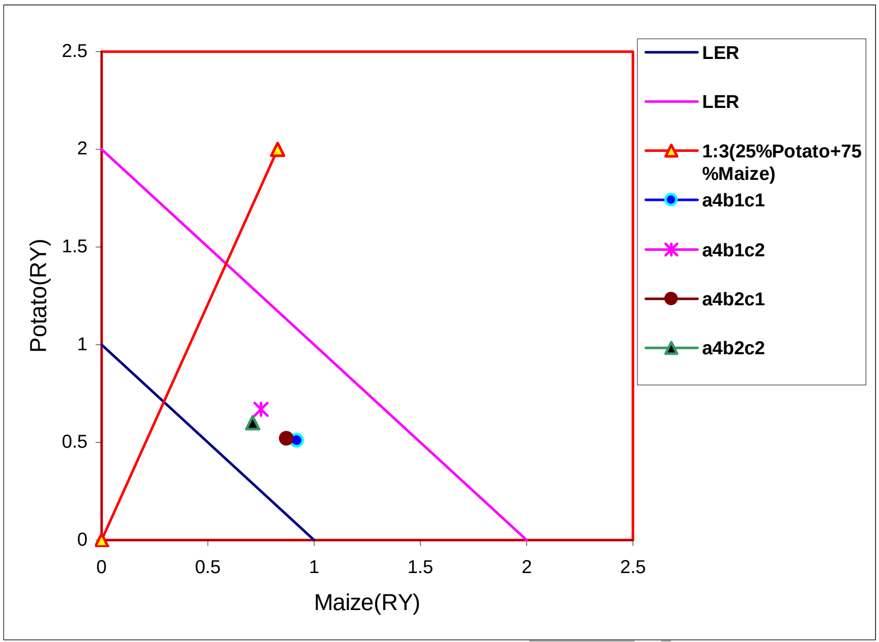

Fig.3. Land equivalent ratio (LER) and Aggresivity in four different density of Maize-Potato intercropping

sole of potato 1:0 a_1b_1	Replacment 3:1 $a_2b_1c_1$	Replacment 1:3 $a_4b_1c_1$	Replacment 1:1 $a_3b_2c_2$
Replacment 1:3 $a_4b_2c_2$	Replacment 1:1 $a_3b_2c_1$	Replacment 1:3 $a_4b_1c_2$	sole of potato 1:0 a_1b_2
Replacment 3:1 $a_2b_1c_2$	Replacment 1:1 $a_3b_1c_1$	Replacment 3:1 $a_2b_2c_2$	Replacment 3:1 $a_2b_2c_1$
Sole of maize 0:1 a_5c_1	Replacment 1:3 $a_4b_2c_1$	Replacment 1:1 $a_3b_1c_2$	Sole of maize 0:1 a_5c_2

Fig.4. Planting plan

4. Discussion

Yield in both sole and intercropping seems to be due to more plant cover and more efficient use of available resources.

Yield was more for both potato and maize in intercropping as compared with sole cropping system. In the case of potato the difference was significant too. In general intercompetence is more for a plant species than its competence with other (different) species. This is because varied species are of different morphologies, root system as well as different peak irrigation water requirement periods. In a suitable combination, plant can complement each other in a more efficient use of environmental resources, mainly light, water and nutrients.

In the ongoing study, the process of photosynthesis was different for the two crops. Potato being of the 3 carbon type has a lower light saturation point and cannot posses high photosynthetic efficacy in lights of high intensities. When row intercropped with maize it is to some extent growing in the shade of maize. In these conditions of lower light intensities, the potato crop will benefit from a more efficient photosynthetic process, along with an increase in the duration of photosynthesis. The effect of factor C (maize plant population) on yield becoming significant in potato-maize intercropping can be considered as a verification of this fact.

Even though the effect of factor A (planting pattern) on maize yield was not significant, yet the highest maize yield was obtained from the intercropping system. Maize yield in half and half treatment of potato and maize (a3b1c1), and in 25% potato, 75% maize (a4b1c1) treatment were respectively 1098 and 274 kg more per ha than in the case of sole cropping of maize. The effect of factor A was not significant either on number of ears per plant or on mean number of kernels per ear, but it showed significance on 1000 kernels weight at 5% level of probability. Number of ears per plant, being a genetic trait, the single cross variety used in the experiments did not become influenced by the planting pattern. Also, the number of kernels per ear since they take their spape from an initial stage in plant's growth, and since in that stage of growth there does not exist any considerable competence between plants (in the sole and intercropping systems) effect of planting pattern on that trait has not become significant. But the effect of planting pattern on the trait, 1000 kernel weight, has become significant because of the plant having made opportune use of the available growing conditions.

Other reasons for higher yields in intercropping as compared to sole cropping could be mentioned as: growing spaces being varied; temporal growth variance between two varying crops; a combined increase in making better use of light, soil moisture content, nutrients as well as a decrease in intercompetition among plants in sole cropping system.

Land Equivalent Ratio (LER) is often the indicator used in determining the efficacy intercropping. LER is the ratio of land needed for sole cropping to land for intercropping. A higher than one ratio is indicative of the fact that intercropping is economical. Here, in the ongoing study LER was higher than unity in all treatments, and therefore intercropping proved to be beneficial.

LER in the most suitable combination was found to be 1.58. This means 58 percent more land needed in sole cropping of the two crops potato and maize to produce 20390 kg/ha of potato, and 8898 kg/ha of maize as compared with thir cultivation in an intercropping system.

In 3:1 planting pattern potato was the dominant plant and maize the less dominating (fig. 1). Maize was the dominant crop while potato the non-dominant in all cases of plant population (fig. 3).

Maximum yield was obtained in the case og high plant population, which means that in spite of increase in plant population, the relative competence between populations of the two crops decreased. In other words, plant intercompetence being less than intracompetance, in an intercropping system, maximum profitability is achieved when accompanied by high plant populations.

In the case of the one plant population treatment where potato population was high as against maize in the mixture, competence did not exist between the two crops (intercompetence was equal to intracompetence (fig. 2), while in the other treatments, maize, because of more plant population proved to be the dominant crop.

Different varying factors, including morphological, physiological and genetic ones dictate the dominance. These factors, along with a consideration of the fact that two morphologically different crop plants have been involved are the causes for the dominance of one crop plant over the other.

Results obtained in the present study arre in agreement with those obtained by other research workers arealization of gools set in the research has largely been achieved.

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