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Original Article

Effect of winter maize-based intercropping systems on maize yield, associated weeds and economic efficiency

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Abstract

A field experiment was conducted during winter seasons of 2003-04 and 2004-05 at Kanpur, India to study the effect of winter maize (*Zea mays* L.) based intercropping systems on maize yield, associated weeds and economics under irrigated condition of central Uttar Pradesh. Thirteen maize-based cropping systems such as maize sole, potato (*Solanum tuberosum* L.) sole, mustard [*Brassica juncea* (L.) Czernj. & Cosson] sole, toria (*Brassica campestris* var. *toria*) sole, pea (*Pisum sativum* L.) sole, linseed (*Linum usitatissimum* L.) sole, wheat (*Triticum aestivum* L. emend. Fiori and Paol.) sole, maize + potato (1:1),maize + mustard (1:1), maize + toria (1:2), maize + pea (1:2), maize + linseed (1:2) and maize + toria (1:2), were tested in randomized block design with three replications. Maize + potato system recorded higher yield attributes and grain yield of maize followed by maize + pea than sole stand of maize. potato was showed most compatible intercrop planted with winter maize as it gave higher maize-equivalent yield, land-equivalent ratio, productivity, monetary returns and lowered weed population, weed dry-biomass and highest weed-control efficiency under irrigated conditions of central Uttar Pradesh. Pea was the next best intercrop with winter maize.

Keywords: competition indices, productivity, weed-control efficiency, winter maize, Zea mays

Efeito dos sistemas consorciados à base de milho de inverno sobre o rendimento de milho, ervas daninhas associadas e eficiência econômica

Resumo

Este experimento foi conduzido durante as estações de inverno de 2003-04 e 2004-05 em Kanpur, Índia, para estudar o efeito do milho safrinha (*Zea mays* L.), em sistemas consorciados com base no rendimento do milho, plantas daninhas e da economia sob condição irrigada, no centro de Uttar Pradesh. Treze sistemas de cultura à base de milho foram testados, somente milho, batata (*Solanum tuberosum* L.), mostarda [*Brassica juncea* (L.) Czernj. & Cosson], toria (*Brassica campestris* var. Toria), ervilha (*Pisum sativum* L.), linhaça (*Linum usitatissimum* L.), o trigo (*Triticum aestivum* L. emend. Fiori e Paol.), milho + batata (1:1), milho + mostarda (1:1), milho + toria (1:2), milho + ervilha (1:2), milho + linhaça (1:2) e milho + toria (1:2), foram testados em delineamento em blocos casualizados com três repetições. O sistema de milho + batata registrou atributos mais elevados de rendimento e produtividade de grãos de milho, seguido pelo milho + ervilha. A batata mostrou-se com entressafra mais compatível com plantação de milho safrinha, uma vez que deu maior rendimento de milho equivalente, produtividade, retorno financeiro e reduziu a população de plantas daninhas, erva-de biomassa seca e maior eficiência no controle de plantas daninhas em condições irrigadas do centro de Uttar Pradesh . A ervilha foi o melhor consórcio com milho safrinha.

Palavras-chave: indices de competição, produtividade, eficiencia do controle de sementes, milhos safrinha, Zea mays

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Introduction

Crop production systems aims to realize high productivity and to promote sustainability over time. This can be achieved mainly through adoption of crop rotation, multiple cropping and intercropping. Intercropping is widely followed practice which has some established and anticipated advantages such as larger yield stability, greater land-use efficiency, increased competitive ability towards weed and augmentation of soil health due to nitrogen fixation. This could be a viable agronomic technology of risk minimizing farmer's income and subsistence oriented, energy efficient and sustainable venture (Faroda et al., 2007). Intercropping also reduces intensity of weeds and offers the possibility of capturing a great share of available resources than in mono-cropping. Besides, it also reduces weeding cost and realizes higher total productivity of the system and monetary return (Pandey & Prakash, 2002).

Since maize is a widely spaced crop, inter-row space could profitably be utilized for other crops in the interspaces particularly in winter season, because in north India the growth of winter maize up to the middle of December remains normal and thereafter due to low temperature it almost ceases till middle of February, leaving enough scope for intercropping during this period to get more returns from a unit area of land. There are many winter crops which may be suitably adjusted in between two rows of winter maize.

Hence, present investigation was planned to augment the possibility of increasing productivity per unit area by introducing suitable intercrops with winter maize under irrigated condition.

Material and Methods

A field experiment was carried out for two consecutive cropping seasons during 2003-04 and 2004-05 at Students' Instructional Farm of C. S. Azad University of Agriculture and Technology, Kanpur. The soil was sandy loam alluvial type, low in organic carbon (0.55%), and available nitrogen (116.8 kg/ha), medium in available phosphorus (18.8 kg/ha) and available potassium (130 kg/ha) with pH 7.6. There were 13 treatment combinations comprising 7 sole crops such as maize (*Zea mays* L.), potato (*Solanum tuberosum* L.), Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson], toria (*Brassica campestris* var. *toria*), pea (*Pisum sativum* L.), linseed (*Linum usitatissimum* L.) and wheat (*Triticum aestivum* L. emend. Fiori and Paol.), and 6 intercropping combinations were tried in randomized block design with 3 replications. The maize varieties 'Sharadmani', potato 'Chipsona-2', mustard 'Kanti', toria 'Bhawani', pea 'Azad P-1', linseed 'T-397' and wheat 'PBW-343' were used. Maize was sown at 60 cm row spacing in sole as well as in intercropping on 1 and 20 November, respectively, in first and second year of experimentation. One row each of potato and mustard, 2 rows of other intercrops were accommodated between 2 rows of maize in additive series. In intercropping, potato was planted on ridges 60 cm apart and maize was sown at the base of the potato ridges. The plant-to-plant distance in potato was 15 cm, in mustard 20 cm and in toria 10 cm, whereas in maize it was 25 cm.

All crops were fertilized with recommended dose of NPK at the rate of 120:60:40 kg for maize, 150:80:100 kg for potato, 120:60:60 kg for mustard, 80:40:40 kg for toria, 20:60:0 kg for pea, 80:40:0 kg for linseed and 150:75:75 kg/ha for wheat in both sole and intercrops. In case of intercropping, the fertilizer dose was adjusted for proportionate area of the intercrops. Full doses of P and K along with one-third N to maize, 50% N to potato, mustard, toria and wheat, and full N to pea and linseed was applied as basal to all the crops in sole as well as intercropping systems. Remaining two-third N to winter maize was top-dressed in 2 equal splits at knee high and tasseling stages. Rest 50% N was applied at the time of earthing to potato and after first irrigation to both mustard and toria crops. However, to wheat crop, remaining N was applied in 2 equal splits at tillering and ear-emergence stages. Fertilizer requirement of all the crops was met through urea, super phosphate and muriate of potash. For comparison between treatments, the yield of all intercrops was converted into maize-equivalent yield (Tomar and Tiwari, 1990).Production efficiency values in terms of kg/ha/day were obtained by MEY of the systems divided by total duration of crops in that system. The concept of monetary-equivalent ratio developed by Adetiloye & Adekunle (1989) for assessing the agronomic as well as economic advantage of various intercropping systems was used. The monetary returns are based on gross values. This is more realistic than the net monetary return for small field plots, where the cost of production are difficult to estimate as pointed out by Adetiloye & Adekunle (1989). Maize-equivalent yield and monetary values of crops was calculated on the basis of minimum support price or prevailing market rate of products. The land-equivalent and monetary-equivalent ratio of component crops and of intercrops were computed for each cropping system. Different competition indices were calculated (Willey, 1979) as per the standard procedures. Weed population and weed dry-biomass were recorded from 0.25 m^2 randomly selected at 3 places in each plot. Weed data were subjected to square-root transformation ($\sqrt{X+0.5}$) before statistical analysis.

Results and Discussion

Growth, yield attributes and grain yield

The dry matter accumulation, yield attributes such as cob weight, grain rows/cob, grains/cob and 100-grain weight, and yield of maize increased significantly when it was intercropped with potato compared with sole cropping of maize and most of the intercropping combinations, however higher values of these were also associated with maize + pea intercropping systems (Table 1). Higher values of these yield attributing characters under maize + potato and maize + pea intercropping systems might be due to improvement in most of the growth parameters under most suitable environmental situation than under other intercropping systems, resulting 22.0 and 7.2 per cent higher maize yield, respectively. Bharati et al. (2007) also reported higher yield attributes and grain yield of winter maize with maize + potato intercropping system. Mustard, toria, wheat and linseed intercropping systems depressed the maize yield to significant level. The maximum yield reduction in toria was due to its exhaustive growth, showing poor compatibility with maize. Mustard and wheat plants approached above the mid height of maize, thus produced shading effect and reduced the penetration of light to the lower leaves of maize plants. Secondly, the lower yield may be attributed to the crowding effect as a result of higher plant density per unit area, resulting in increased intra-row competition. The maturity of these crops coincides with full growth of maize. This provides the reason for drastic depression of maize yield. Reduction in maize yield under these intercropping systems might be due to more competition for sunlight, CO_2 and space. The result confirms the findings of Sinha et al. (1999), Patra et al. (2000) and Bharati et al. (2007).

Inclusion of intercrops with winter maize gave higher maize-equivalent yield (MEY) and productivity (kg/ha/day) compared with sole cropping of maize (Table 2). This was mainly due to additional advantage of intercrops yield and higher economic values of intercrops. Among the intercropping systems, maize + potato showed significantly higher MEY and productivity (kg/ha/day) followed by maize + pea. An increase of 176.4 and 85.6% MEY in maize + potato and maize + pea over sole maize was noticed. The highest MEY and productivity under these treatments was owing to higher maize yield in addition to intercrop potato and pea yield. Maize + mustard and maize + linseed although gave significantly higher MEY than sole stand of maize but both the systems showed at par MEY. Similarly, maize + linseed recorded higher MEY and productivity than maize + wheat. However, significantly lower values of MEY and productivity were obtained under maize + toria combination. Bharati et al. (2007) also reported higher and lower maize-equivalent yield under maize + potato and maize + toria intercropping system, respectively.

Weeds

The dominant weed flora recorded in the experimental field was *Cyperus rotundus* L., *Chenopodium album* L., *Convolvulus arvensis* L. *Anagallis arvensis* L. and *Melilotus alba* L. Intercropping systems significantly reduced the weed population and weed dry-biomass than sole stand of maize (Table 2). A significant reduction

Table 1. Effect of intercropping systems on yield attributes of maize and yield of component crops (pooled data of 2 years).

Treatment	Dry-weight at harvest (g/plant)	Cob length (cm)	Cob weight (g)	Grain rows/ cob	Grains/ cob	100-grain weight (g)	Grain yield of component crops (tonnes/ha)		Mean yield index	
							Maize	Intercrop	Maize	Intercrop
Sole maize	292.71	19.72	106.75	13.98	372.52	22.45	4.99			
Sole potato								22.38		
Sole mustard								1.64		
Sole toria								0.90		
Sole pea								1.69		
Sole linseed								0.97		
Sole wheat								4.45		
Maize + potato (1:1)	320.87	20.64	129.78	14.36	426.85	24.60	6.09	20.49	122.0	91.6
Maize + mustard (1:1)	201.15	17.35	80.75	13.08	296.58	19.93	3.38	1.25	67.7	76.4
Maize + toria (1:2)	187.73	16.04	83.73	13.34	294.48	19.96	2.76	0.77	55.3	85.1
Maize + pea (1:2)	313.44	20.26	119.09	14.08	392.23	23.17	5.35	1.28	107.2	76.1
Maize + linseed (1:2)	247.80	18.48	96.10	13.78	349.81	21.20	4.66	0.81	93.4	83.3
Maize + wheat (1:2)	189.95	15.32	78.33	13.46	294.88	19.89	3.12	3.07	62.5	68.9
SEd±	4.00	0.62	5.03	0.14	10.67	0.76	0.13	0.15		
CD (P=0.05)	8.27	1.27	10.38	0.30	22.01	1.57	0.26	0.30		

Table 2. Effect of intercropping systems on maize-equivalent yield, associated weeds and competition indices (pooled data of 2 years).

Treatment	Maize-equivalent yield (tonnes/ha)	Productivity (kg/ha/day)	Weed population/m² (90 DAS)	Weed dry-biomass (g/m²) (90 DAS)	Weed control efficiency (%)	Land equivalent ratio			Competitive ratio		Aggressivity index
						Maize	Intercrop	Total	Maize	Intercrop	
Sole maize	4.99	35.65	6.71 (44.5)	18.26		1.00		1.00			
Sole potato	8.41	78.60					1.00	1.00			
Sole mustard	4.99	40.92					1.00	1.00			
Sole toria	2.92	25.15					1.00	1.00			
Sole pea	5.14	42.15					1.00	1.00			
Sole linseed	2.97	24.12					1.00	1.00			
Sole wheat	5.27	41.46					1.00	1.00			
Maize + potato (1:1)	13.79	98.51	4.33 (18.3)	9.10	58.9	1.21	0.92	2.13	1.31	0.76	0.31
Maize + mustard (1:1)	7.20	51.39	5.18 (26.3)	13.10	40.9	0.67	0.76	1.43	0.88	1.13	(-)0.09
Maize + toria (1:2)	5.24	37.42	4.55 (20.2)	10.15	54.6	0.56	0.85	1.41	1.30	0.75	0.13
Maize + pea (1:2)	9.26	66.16	4.43 (19.2)	9.65	56.8	1.08	0.75	1.83	2.88	0.34	0.69
Maize + linseed (1:2)	7.13	50.95	4.89 (23.4)	10.98	47.4	0.93	0.83	1.76	2.24	0.44	0.52
Maize + wheat (1:2)	6.77	48.34	4.96 (24.1)	10.80	45.8	0.63	0.69	1.32	1.82	0.53	0.28
SEd±	0.18		0.16	0.41				0.05			
CD (P=0.05)	0.37		0.33	0.85				0.10			

Original data given in parentheses are subjected to square-roottransformation($\sqrt{x + 0.5}$)

in weed population and their dry-biomass was recorded in maize + potato combination, closely followed by maize + pea system. Weed-control efficiency of these intercropping systems was also higher in order than other intercropping combinations. This may be attributed to relatively less space available for the growth of the weeds from the early stage of crop growth and more shading effect due to lateral growth of potato plants between two rows of maize (Sinha et al., 1999). Maximum weed population and weed dry-biomass were recorded in maize + mustard intercropping system. This might be due to slow initial growth wider row spacing of mustard providing conducive conditions for growth of weeds. The weed population recorded with maize + pea and maize + toria were at par and both were significantly lower than remaining intercropping systems. Similarly, a lower weed dry-biomass was also recorded with these treatments but these were significantly lower than other intercropping combinations.

Competition indices

The mean land-equivalent ratio (LER) was 1.32-2.13 in various maize-based intercropping systems, indicating higher agronomic advantage from it over sole cropping (Table 2). The higher values of LER (2.13) were recorded from maize + potato followed by maize + pea (1.83) intercropping combination, indicating that both the systems as a whole was more productive, giving 113 and 83 per cent more yield respectively. This was possible due to greater temporal complementarily.

Maize appeared to be more competitive than all the intercrops with higher competitive ratio except when it was planted with mustard. However, maize was more dominant over pea and was less dominant over mustard with the highest (2.88) and lowest (0.88) values of competitive ratio respectively. Pea, linseed and wheat offered less competition to maize crop, providing competitive ratio of 0.34, 0.44 and 0.53 respectively. Intercropping of pea with maize recorded higher aggressivity index (0.52) than other intercropping systems followed by maize + linseed and maize + potato (Table 2). The aggressivity index of maize + mustard was negative.

Economic efficiency

Most of the intercropping systems were more remunerative than sole cropping (Table 3). Intercropping system of maize + potato recorded the highest total monetary returns and monetary efficiency (Rs/ha/day), followed by maize + pea, maize + wheat, maize + linseed, maize + mustard and maize + toria. The lower of these values may be attributed to the lower value of combined produce of component crops due to reduction in yield. Even after obtaining substantial agronomic advantage from intercropping, only 2 intercropping systems, viz. maize + potato and maize + pea gave on economic advantage of 66% (monetary-equivalent ratio 1.66) and 14% (monetary-equivalent ratio 1.14), whereas the remaining intercropping treatments revealed loss in economic advantage (monetary-equivalent ratio 0.63 to 0.90) which was perhaps due to low grain yield obtained from the system.

Maize intercropped with potato gave the highest relative value total an relative net returns, followed by maize + pea combination (Table 3). Higher maize-equivalent yield and market price of potato and pea in these intercropping systems enhanced the relative value total by 176 and 85% with the highest values of relative net returns of 1.91 and 1.72 in order respectively. These findings are in agreement with the observation of Patra et al. (2000). The minimum relative value total (1.05) and relative net return (0.95) values were recorded in maize + toria intercropping system.

Table 3. Economic efficiency of winter maize-based intercropping systems (pooled data of 2 years).

Treatment	Monetary returns (x 10^3Rs/ha)			Monetary-equivalent ratio			Monetary efficiency (Rs/ha/day)	Relative value total	Relative net returns
	Maize (ra)	Intercrop (rb)	Total	Maize (ra/Rb)	Intercrop (rb/Rb)	Total			
Sole maize	28.10		28.10	0.62		0.62	200.71	0.00	0.00
Sole potato		44.76	44.76		1.00	1.00	418.27	0.00	0.00
Sole mustard		26.54	26.54		0.59	0.59	217.52	0.00	0.00
Sole toria		15.48	15.48		0.34	0.34	133.43	0.00	0.00
Sole pea		28.06	28.06		0.61	0.61	229.99	0.00	0.00
Sole linseed		15.79	15.79		0.35	0.35	128.34	0.00	0.00
Sole wheat		34.08	34.08		0.76	0.76	268.31	0.00	0.00
Maize + potato (1:1)	32.11	42.96	75.07	0.71	0.55	1.66	536.20	2.76	1.91
Maize + mustard (1:1)	18.88	20.26	39.14	0.42	0.45	0.87	279.59	1.44	1.28
Maize + toria (1:2)	15.28	13.14	28.41	0.34	0.29	0.63	202.93	1.05	0.95
Maize + pea (1:2)	30.23	21.35	51.58	0.67	0.47	1.14	368.42	1.85	1.72
Maize + linseed (1:2)	26.40	13.12	39.52	0.58	0.29	0.87	282.31	1.43	1.33
Maize + wheat (1:2)	17.39	23.60	40.99	0.38	0.52	0.90	292.76	1.35	1.14
SEd±			0.98					0.04	0.04
CD (P=0.05)			1.97					0.08	0.07

ra = monetary return of maize; rb = monetary return of intercrops; Rb = highest sole crop monetary return

Conclusions

Thus it can be concluded that potato was showed most compatible intercrop planted with winter maize as it gave higher maize-equivalent yield, land-equivalent ratio, productivity, monetary returns and lowered weed population, weed dry-biomass and highest weed-control efficiency under irrigated conditions of central Uttar Pradesh. Pea was the next best intercrop with winter maize.

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