



Enhancing productivity of spring maize (*Zea mays*) with intercrops and row-orientations

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ABSTRACT

A research experiment was conducted on spring maize (*Zea mays* L.) in a split-plot design with two row orientations in main plots and nine intercropping including sole systems in sub plots during 2016-17 at Punjab Agricultural University, Ludhiana. Row orientation did not significantly influence the growth and yield of spring maize. Spring maize equivalent yield and net returns recorded from various intercropping systems remained at par with north-south and east-west row orientation. Spring maize + spring groundnut intercropping system recorded significant higher growth and development parameters of spring maize and remained at par with spring maize + summer squash, sole spring maize and spring maize + maize (fodder) but significantly higher than spring maize + spinach. Spinach recorded highest value of aggressivity (0.42) and gave maximum competition to spring maize. Spring maize equivalent yield, net returns, land equivalent ratio and area time equivalent ratio were significantly higher under spring maize + summer squash system as compared to all other systems. Spring maize + summer squash proved highly productive, profitable and viable intercropping system which gave 92.4% higher spring maize equivalent yield and ₹ 60200 ha⁻¹ higher net returns in comparison to sole spring maize.

Key words: Competitive indices, Equivalent yield, Intercropping system, PAR interception, Spring maize

The intercrops should be sown in suitable direction for best utilization of solar radiation. In bed planted wheat based intercropping systems, crops in east-west row orientation resulted in maximum productivity, monetary as well as intercropping advantage as compared to north-south row orientation (Pandey and Singh 2018). Canopy temperature and photosynthetic efficiency is changed as row orientation affects interception and transmission of solar radiation by the crop canopy (Drews *et al.* 2009). Yield advantages under intercropping systems vary as per level of competition between component crops. Several indices of intercropping systems, viz. land equivalent ratio (LER), area time equivalent ratio (ATER), competitive ratio (CR) and aggressivity have been proposed to describe competition and economic advantages (Dhima *et al.* 2007).

It is observed that majority of farmers in Punjab have adopted rice-wheat cropping system but some potato growing farmers have adopted rice-potato-spring maize cropping system. By growing suitable intercrops in spring maize (*Zea mays* L.), this cropping system will become more productive and viable. In spring maize, there is possibility of

growing summer squash, maize (fodder), spring groundnut and spinach. Summer squash and spinach are being a low statured crops and their sowing in February, will help to fetch higher price when there is no glut in market. Maize (fodder) can provide green fodder during lean period of its availability. Spring groundnut is being a leguminous crop helps to promote growth of cereal crops (Karanja *et al.* 2014). Under bed planting method spring maize and intercrop can be sown at the bed top and irrigation water can be applied into furrows. At present, groundwater level is declining in north-western India and it is well established that bed planting method is an important resource conservation technology which results in saving of irrigation water, reducing lodging and improving productivity as compared to flat planting (Hira *et al.* 2004). Therefore present research experiment was planned while considering all these facts.

MATERIALS AND METHODS

A field experiment was conducted during spring season of 2016-17 at student's research farm, Punjab Agricultural University, Ludhiana (30° 54' N latitude and 75° 48' E longitude). During 2016 (February-June) mean weekly maximum temperature was ranged between 20.5-42.6°C, minimum temperature was 7.5-28.9°C and total rainfall received was 164.1 mm, while second year maximum temperature was ranged between 19.8-41.6°C, minimum

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temperature was 8.2-27.3°C and total rainfall received was 220 mm. Soil of experimental field was loamy sand in texture (79.5% sand, 8.2% silt, 13.1% clay) and medium in fertility status. Experiment was conducted in a split plot design. Two row-orientations were kept in main plots and nine treatments comprising spring maize based intercropping systems and sole planting systems were kept in sub plots. Wheat bed planter was used for bed preparation (bed width was 37.5 cm and furrow width was 30 cm). At top of the bed one side spring maize, another side intercrop was sown. Spring maize variety PMH 10, spinach variety Punjab Green, maize (fodder) variety J 1006, groundnut variety SG 84 and summer squash variety Punjab Chappan Kadoo 1 were sown on 1st week of February. Component crops were supplied with 100% recommended dose of fertilizers on area basis under intercropping and sole cropping systems. Two hand weedings were given at 30 and 50 DAS. Number of irrigations varied from 10 to 12 depending upon the rainfall during growing seasons and furrow method of irrigation was adopted.

Sun Scan Canopy Analyzer instrument was used for recording leaf area index (LAI) of spring maize. Cob length of spring maize was measured with scale and vernier caliper instrument was used for measuring cob girth. To calculate economic returns market price of spring maize was ₹ 13.65/kg in 2016 and ₹ 14.25/kg in 2017, groundnut was ₹ 42.20/kg in 2016 and ₹ 44.00/kg in 2017. Market price of spinach ₹ 4.50/kg, summer squash ₹ 6.00/kg, maize fodder ₹ 2.10/kg and spring maize stover ₹ 1.40/kg during both the years.

Yield of intercrops was converted to spring maize equivalent yield (SMEY) on basis of market price of component crops;

$$\text{SMEY} = \text{Grain yield of spring maize} + \frac{\text{Yield of intercrops} \times \text{Price of intercrops}}{\text{Price of spring maize}}$$

Spring maize was harvested manually on 1st week of June. Grain yield was adjusted to 15% moisture level. Two cuttings of spinach were taken, 1st at 30 DAS and subsequent at 40 DAS. Harvesting of maize (fodder) was done at 45 DAS. Total 10 pickings of summer squash were taken, first at 60 DAS and subsequent pickings were at two to three days intervals, its duration was 100 days. Digging of spring groundnut was done on 2nd week of June. For statistical analysis of data, CPCS-I software and technique analysis of variance (ANOVA) was used. For comparing treatment mean 5% level of significance was kept.

RESULTS AND DISCUSSION

Growth and yield attributes of spring maize: Effect of row orientations was non-significant on plant height, dry matter accumulation, leaf area index, cob length, cob girth and grain weight per cob of spring maize but the increase was observed in north-south row orientation over east-west (Table 1). It was due to slightly higher interception of solar radiation under north-south direction (Fig 1) that resulted higher production of photo-assimilates during vegetative phase which were transferred for development of grains. Research findings were supported by Reddy (2004). But

Table 1 Growth attributes, yield attributes and yield of spring maize, intercrop yield, spring maize equivalent yield and net returns as influenced by row orientations and intercropping systems at harvest (pooled data of two years)

Treatment	Plant height (cm)	DMA (g/plant)	LAI	Cob length (cm)	Cob girth (cm)	Grain weight per cob (g)	Grain yield (kg/ha)	Stover yield (kg/ha)	Intercrop yield (kg/ha)	Spring maize equivalent yield (kg/ha)	Net returns (×10 ³ ₹/ha)
<i>Row orientations</i>											
East-West	169.6	185.6	2.13	15.5	12.3	75.7	5740	12215	11010	6380	65.3
North-South	171.3	187.7	2.19	15.6	12.6	76.9	6005	12785	10920	6560	68.4
SEm±	1.6	0.2	0.03	0.1	0.2	0.3	75	160	-	102	0.4
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	NS
<i>Intercropping systems</i>											
Sole spring maize	173.9	189.0	2.21	15.9	12.6	76.8	5940	12715	-	5940	67.2
Spring maize + maize (fodder)	169.2	187.3	2.14	15.6	12.5	76.4	5810	15270	14430	7980	87.9
Spring maize + spinach	158.5	175.8	1.78	14.1	12.0	72.0	5440	11425	4560	6910	75.0
Spring maize + spring groundnut	176.2	191.0	2.36	16.3	12.8	79.0	6135	13140	210	6810	70.8
Spring maize + summer squash	174.6	190.0	2.31	16.1	12.6	77.9	6035	12970	12520	11430	127.4
Sole maize (fodder)	-	-	-	-	-	-	-	-	26130	3940	37.0
Sole spinach	-	-	-	-	-	-	-	-	11670	3760	37.1
Sole groundnut	-	-	-	-	-	-	-	-	1320	4190	30.4
Sole summer squash	-	-	-	-	-	-	-	-	16880	7270	69.3
SEm±	2.9	1.3	0.12	0.2	0.2	0.6	139.5	299	-	146	0.9
CD (P= 0.05)	9.5	11.4	0.33	0.8	0.6	4.7	510	900	-	580	3.6

Interaction – NS

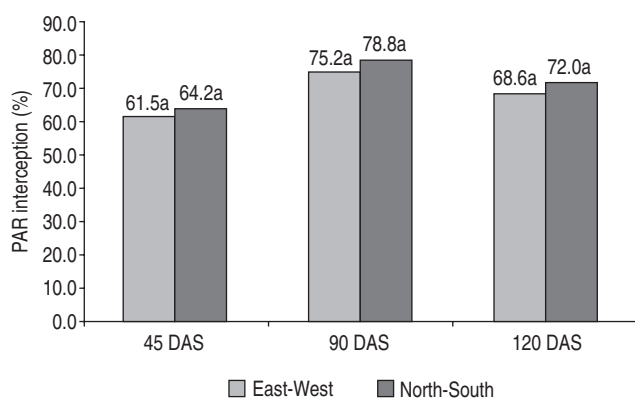


Fig 1 PAR interception of spring maize based intercropping systems as influenced by row orientations (pooled data of two years).

contrary to results reported by Abdel-Maksoud (2008), however Karanja *et al.* (2014) documented increase in plant height of sorghum with N-S direction under sorghum + cowpea intercropping system. Among intercropping systems, spring maize + spring groundnut recorded significantly higher values of growth and yield attributes of spring maize as compared to spring maize + spinach system but was at par with spring maize + summer squash, sole spring maize and spring maize + maize (fodder) intercropping system. Khoroar and Patra (2014) also reported positive effect of intercropping leguminous crops in maize. But spinach possessed dense growth near the root system of spring maize and gave severe competition (Table 2), which was responsible for suppressing growth of spring maize. Under spring maize + spinach intercropping system plant height

Table 2 Competitive indices of spring maize based intercropping systems (pooled data of two years)

Treatment	LER	ATER	Aggressivity		CR	
	Intercropping system		Spring Maize	Inter-crop	Spring maize	Inter-Crop
Row orientations						
East-West	1.45	1.23	0.06	-0.06	1.41	0.98
North-South	1.46	1.25	0.08	-0.08	1.60	0.92
SEm±	0.06	0.05	0.02	0.02	0.03	0.04
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Intercropping systems						
Spring maize + maize (fodder)	1.54	1.20	-0.27	0.27	0.82	1.25
Spring maize + spinach	1.32	1.06	-0.42	0.42	0.71	1.47
Spring maize + groundnut	1.20	1.15	0.68	-0.68	3.07	0.34
Spring maize + summer squash	1.77	1.54	0.28	-0.28	1.42	0.75
SEm±	0.04	0.03	0.03	0.03	0.06	0.04
CD (P=0.05)	0.11	0.08	0.05	0.04	0.17	0.12

Interaction – NS

decreased by 8.9% and dry matter accumulation by 7.0% as compared to sole spring maize. Kumar *et al.* (2006) also observed significant reduction in growth of maize under maize + spinach intercropping system.

Grain and stover yield of spring maize: Row orientation did not significantly influence grain and stover yield of spring maize but small increase of 4.4% in grain and stover yield was observed under north-south row orientation over east-west (Table 1). Increase in yield was attributed to slight increase in growth and yield attributes of spring maize under north-south direction. Karanja *et al.* (2014) earlier mentioned that sorghum + cowpea intercropping system under N-S direction gave significantly higher grain yield of sorghum. Among the intercropping systems, significantly higher grain yield and stover yield of spring maize were recorded under spring maize + spring groundnut than spring maize + spinach intercropping system but was statistically at par with spring maize + summer squash, sole spring maize and spring maize + maize fodder intercropping system. Increase in grain yield of spring maize was 3.2% higher when intercropped with groundnut and 1.6% higher when intercropped with summer squash as compared to sole spring maize crop because of complementarity in use of resources like light, nutrients and moisture *etc* under intercropping system. Results were in conformity with the research findings of Adhikari *et al.* (2005). Reduction in grain and stover yield of spring maize when intercropped with spinach was attributed to significant decrease in growth and yield attributes of spring maize due to the sufficient competition imposed by spinach.

Photosynthetically active radiation (PAR) interception: Interception of solar radiation within crop canopy directly affects photosynthetic efficiency of a crop. There was non-significant effect of row orientations on PAR interception (Fig 1) but slight increase of 4.4% at 45 DAS, 4.8% at 90 DAS and 5% at 120 DAS was recorded under north south direction as compared to east-west direction. Results were confirmed by the research findings of Abdel-Maksoud (2008). Among the intercropping systems, significantly higher PAR interception (69.9%) was recorded under spring maize + maize (fodder) intercropping system at 45 DAS (Fig 2), which was attributed to fast growth of maize (fodder) at early stages forming dense canopy under intercropping system than the other component crops. While observing critically, PAR interception was statistically at par under spring maize + summer squash, spring maize + spring groundnut and sole spring maize system, as slower growth of groundnut and summer squash during early stage. But spinach had adversely affected the growth of spring maize which was responsible for significantly lower PAR interception under spring maize + spinach intercropping system at 45 DAS. At 90 DAS, significantly higher PAR interception (86.7%) was observed under spring maize + summer squash because of larger size of summer squash leaves, covered maximum part of soil and also helped in conserving soil moisture. PAR interception was recorded lowest under spring maize + spinach system among other

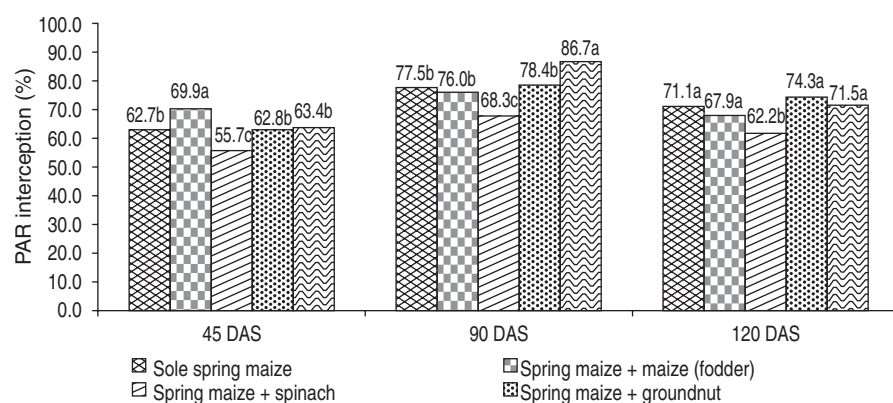


Fig 2 PAR interception of spring maize based intercropping systems as influenced by intercropping systems (pooled data of two years).

intercropping system at 90 DAS. At 120 DAS, PAR interception was statistically similar under spring maize + groundnut, spring maize + summer squash, sole spring maize and spring maize + maize (fodder) intercropping system but it was significantly lower where spinach was grown as intercrop with spring maize. Spinach had dense rooting pattern which possessed highest competition for available resources and ultimately suppressed the canopy size of spring maize. Panhale *et al.* (2016) and Chaudhary *et al.* (2016) mentioned higher interception of solar radiation under maize/sorghum + legume intercropping system.

Intercropping indices: LER and ATER of spring maize based intercropping systems was not significantly affected by row orientations (Table 2). Among different intercropping systems, values of LER and ATER were greater than unity which indicated yield advantages over sole planting of spring maize. Spring maize + summer squash intercropping system recorded significantly higher values of LER (1.77) and ATER (1.54) in comparison to other intercropping systems indicating higher land utilization advantages and per day productivity over sole planting system. The yield advantages were possible due to greater temporal and spatial complementarity between component crops. Similar findings were reported by Pandey *et al.* (2015) in wheat based intercropping systems. Values of aggressivity and CR for spring maize and intercrops were not influenced significantly by row orientations but values of aggressivity and CR for spring maize were higher under north-south direction. Because of this reason slight increase was observed in growth and development of spring maize under north-south direction, although the differences were non-significant. On the other hand, spring maize was dominant species under spring maize + groundnut system with significantly higher values of aggressivity and higher values of CR over other intercropping systems. It indicated more vigorous growth of spring maize which was more competitive to groundnut. Takim (2012) observed dominant effect of maize as the positive values of aggressivity when legumes were grown as intercrops. Padhi and Panigrahi (2006) mentioned higher values of CR (2.48) for maize and lower values for groundnut (0.40) under intercropping

system. Among different intercrops, spinach was more competitive towards spring maize followed by maize (fodder). Under spring maize + spinach values of aggressivity (0.42) and competition ratio (1.47) were significantly higher for spinach in comparison to other intercrops, clearly indicating that spinach had suppressed the growth and development of spring maize under intercropping system.

Intercrop yield, spring maize equivalent yield and economic returns: The data (Table 1) revealed that summer squash produced 75%

fruit yield, maize fodder produced 55% green fodder yield, spinach produced 40% fresh yield and spring groundnut produced 15.9% pod yield under intercropping system in comparison to their respective sole planting systems. Yield potential of summer squash was highest among the intercrops because of complementary effect exist in utilization of resources. Summer squash helped to make suitable microclimate which had recorded higher values of PAR interception (Fig 2) and contributed for efficiently utilization of available resources by component crops. But pod yield of groundnut was reduced by large extent (84.1%) under intercropping system in comparison to its sole planting, results were supported by the research findings of Sekhon *et al.* (2018) and Khoroar and Patra (2014). Frequent irrigation under spring maize based intercropping system increased the height of groundnut which adversely affected insertion of pegs into soil, secondly shading effect of main crop adversely affected the flowering and peg formation.

North-south row orientation recorded comparatively higher spring maize equivalent yield (2.8%) and net returns (₹ 3100/ha) in comparison to east-west direction (Table 1) but differences did not differ significantly. Among various intercropping systems, spring maize + summer squash produced 92.4%, spring maize + maize (fodder) produced 34.3%, spring maize + spinach produced 16.3% and spring maize + groundnut produced 14.7% higher spring maize equivalent yield as compared to sole spring maize system. Spring maize + summer squash produced significantly higher net returns (₹ 127.4 × 10³) and this system was followed by spring maize + maize fodder (₹ 87.9 × 10³). It was observed that summer squash having medium duration, higher yield potential with good market price and less competitive (Table 2), therefore it proved more profitable and viable option than other intercrops. Maize fodder also fetched comparatively good market price during the month of March which is a lean period for fodder availability

It can be concluded from above investigation that intercropping of summer squash in bed planted spring maize was highly productive, profitable and viable option preferably under north-south row orientation. Besides this system, spring maize + maize fodder proved second best

intercropping system, providing comparable grain yield of spring maize and additional green fodder supply during lean period of fodder availability.

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