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Research Paper

Production potential and economic viability of bed planted wheat (*Triticum aestivum*) as influenced by different intercropping systems and levels of nutrients applied to intercrops

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ABSTRACT

A field experiment was conducted at the Punjab Agricultural University, Ludhiana, during the winter (*rabi*) seasons of 2012–13 and 2013–14 in a split-plot design with 3 replications. The main plots treatments involved 5 intercropping systems, viz. wheat (*Triticum aestivum* L.) + spinach (*Spinacia oleracea* L.), wheat + fenugreek (*Trigonella foenum-graccum* L.), wheat + fodder oats (*Avena sativa* L.), wheat + canola (*Brassica napus* L.) and wheat + linseed (*Linum usitatissimum* L.). Each main plot was divided into 4 subplots to allocate the different levels of recommended dose of nutrients, i.e. 0, 50, 75 and 100% of recommended dose of nutrients to intercrops. Higher biological, straw and grain yields of wheat were observed in wheat + spinach (12.17, 6.77, 5.40 t/ha) intercropping system which was statistically at par with wheat + fenugreek (12.01, 6.72, 5.29 t/ha) and wheat + fodder oats (11.74, 6.61, 5.12 t/ha), but significantly higher than wheat + linseed (11.37, 6.29, 5.07 t/ha) and wheat + canola (10.39, 5.64, 4.75 t/ha) intercropping system. Significantly lowest values biological, straw and grain yield were observed in wheat + canola intercropping system than the rest of the intercropping systems. Wheat + fodder oats intercropping system exhibited significantly higher wheat-equivalent yield, system productivity and the economic returns followed by the wheat + spinach intercropping system compared with the other intercropping systems. With the increased dose of nutrients from 0 to 100% applied to intercrops on area basis, there was progressive increase in yield of intercrops. The application of 100% recommended dose of nutrients to the intercrops resulted in significantly higher value of wheat-equivalent yield, system productivity and economic returns than the other recommended dose of nutrients applied to the intercrops.

Key words: Bed-planted wheat, Intercropping systems, System productivity, Wheat-equivalent yield

The population of the developing countries like India is increasing day by day but the food production remains stagnant due to low crop productivity and limited resources. So, there is need for increasing production of foodgrains per unit of the resource availability. Small farmers in many countries are getting low production due to limited resources. Intercropping is a possible way of increasing the productivity on small farms, as it provides security against potential losses of monoculture. Intercropping increases diversity in the cropping system and results in higher yield on a certain piece of land by making more effective usage of the existing growth resources such as light, heat and water with a combination of crops of diverse rooting ability, canopy arrangement, height and nutrient requirements based on the corresponding exploitation of growth resources by the component sole crops (Lithourgidis *et al*., 2011; Eskandari, 2011). Chapagain and Riseman (2014) also reported that intercropping improved the biomass, nitrogen and grain protein content compared with monoculture. Therefore, in modern agriculture, it can help to increase crop productivity particularly at small farms as it satisfies the diversified demands of the farm people (Imran *et al*., 2011). As conventional agriculture systems become dominated by monospecific crops, nutrient cycles become more open and therefore more susceptible to losses through leaching, run-off and volatilization (Crews and Peoples, 2005). Growing two or more than two crops in the same field at the same time as in intercropping system increases efficient utilization of

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available nutrients, reduces nutrient leaching and increases nutrient cycling, through complementary resource partitioning. This in turn can decrease the amount of external fertilizer inputs. The greatest limitation of increasing the productivity of crops in intercropping system is the inadequate supply of nutrients, as most of the soils are poor in native fertility and continuous application of fertilizers even in balanced form may not sustain soil fertility and productivity. Thus, balanced fertilization along with sound crop husbandry provides a great scope for increasing productivity. Presently, sole wheat is grown in Punjab. In bed-planted wheat, there is scope of growing some intercrops in furrows during early growth stages of crop. The production potential of bed-planted wheat and different intercrops may also vary in relation to the intercropping systems and different levels of nutrients applied to intercrops.

MATERIALS AND METHODS

The experiment was carried out during the winter (*rabi*) seasons of 2012–13 and 2013–14 at research farm of Department of Agronomy, Punjab Agricultural University, Ludhiana (30º 54’ N, 75º 48’ E, 247 m above the mean sea-level). The soil of the experimental field was loamy sand with *p*H 7.2. It was moderately fertile, being low in organic carbon (0.26%), available nitrogen (81.5 kg/ha), available potassium (103.0 kg/ha) and medium in available phosphorus (17.5 kg/ha). Sowing of wheat on beds was done with the help of a bed planter, which enables 2 wheat rows, 20 cm apart on 37.5 cm wide bed and makes 30 cm wide furrow between 2 beds and intercrops were sown in consecutive furrows. Sowing time for the wheat variety ‘PBW 621’ and intercrops was 9 November 2012 and 12 November 2013 respectively. The control of weeds on both beds and furrow was done by hand-weeding. Other package of practices for wheat and intercrops were followed as per PAU recommendations. Wheat and intercrops were sown in 2 : 1 row arrangement. The experiment was laid out in a split-plot design with 3 replications with 5 intercropping systems, i.e. wheat + spinach, wheat + fenugreek, wheat + fodder oats, wheat + canola and wheat + linseed, in the main plots. Each main plot was divided into 4 subplots to allocate the different levels of recommended dose of nutrients, i.e. 0, 50, 75 and 100% to intercrops. The nitrogen, phosphorus and potash were applied through urea, single superphosphate and muriate of potash respectively.

During 2012–13, it rained 162.0 mm in 13 rainy days (no rainfall during October and November, 17.4 mm in December, 8.2 mm in January, 96.4 mm in February, 35.6 mm in March and 4.4 mm in April), whereas during 2013–14, total 227.0 mm rainfall in 18 rainy days with reasonable distribution was received (36.2 mm in October, 4.6 mm in November, 28.0 mm December, 55.5 mm in January, 36.7 mm in February, 35.0 mm in March and 31 mm in April). The intercropping systems were evaluated in terms of wheat-equivalent yield (q/ha), system productivity (kg/ha/day) and economic returns. Economic returns (₹/ha) for individual crop in intercropping system were calculated on the basis of prevailing market rates of inputs and selling price of produce. The system productivity was calculated by converting the yield of all crops grown in intercropping system in terms of wheat-equivalent yield in kg/ha and dividing it with the duration of intercropping system. It was expressed as kg/ha/day. Yield of individual crop was converted into equivalent yield (q/ha) on the basis of prevailing market price of the crop. It was calculated by the following formula:

$$\text{WEY} = \text{Grain yield of wheat} + \frac{\text{Yield of intercrops} \times \text{Price of intercrops}}{\text{Price of wheat}}$$

The average prices (2 years) of wheat, canola and linseed grain and straw for calculation of WEY and economic returns were taken as 13,880, 28,770, 34,000, 2,000, 1,000, 100₹/t respectively. The average prices (2 years) of spinach, fenugreek and oats fodder were 3,500, 4,500 and 1,560₹/t respectively.

RESULTS AND DISCUSSION

Meteorological observations

In this research experiment, the meteorological data showed marked variation in weather conditions during the 2 years of experiment (Table 1). Precipitation during the crop season during 2013–14 was equally distributed and 65.0 mm higher than the crop season during 2012–13. Consequently, to meet the water requirement of crops more irrigation was given during the first year than the second. Heavy rainfall in February (96.4 mm) during 2012–13, resulted in the lodging of the wheat, canola and linseed crop grown as sole or intercropped. Average temperature during February–April coinciding with the reproductive and maturity stages of the wheat, canola and linseed crops remained lower during 2013–14 than the crop season of 2010-13 which elongates the growing periods of these crops and resulted in better yield of wheat, canola and linseed crop during 2013–14.

Yield-attributing characters

There was significant effect of intercropping systems on ears/meter row length. Among the intercropping systems, ears/m row length were maximum in wheat + spinach intercropping system (82.6) which was statistically at par with wheat + fenugreek, wheat + fodder oats and wheat + linseed but significantly higher than wheat + canola intercropping system during both the growing seasons. On the basis of pooled analysis of 2 years data, the highest number of ears/m row length and grains/ear was recorded in wheat + spinach intercropping system which was statistically at par with wheat + fenugreek and wheat + oats fodder but significantly higher than wheat + linseed and wheat + canola intercropping systems. Wheat + canola intercropping system showed the lowest values of ears/m row length and grains/ear than the other intercropping systems. Kumar (2008) and Khan *et al*. (2005) also reported the similar findings that wheat intercropped with Indian mustard resulted in significantly lower grain yield and yield attributes. The data showed ears/m row length and grains/ear were non-significantly influenced by different doses of nutrients applied to intercrops (Table 2). Wheat crop sown on raised bed and fertilized with 100% recommended dose of nutrients, whereas different levels of recommended dose of nutrients to intercrops were applied in furrows due to this competition between wheat and the component crops for the resources were minimum. Yield attributes (ear weight, ear length and 1,000-seed weight) were not affected significantly in relation to the intercropping systems and different levels of nutrients applied to intercrops.

Biological, grain and straw yield of wheat and yield of intercrops

The pooled data presented in Table 3 depicted that among the intercropping systems higher biological, straw and grain yields of wheat were found in wheat + spinach (12.17, 6.77, 5.40 t/ha) intercropping system which was statistically at par with wheat + fenugreek, wheat + fodder oats but significantly higher than wheat + linseed and wheat + canola intercropping systems. Significantly lowest values biological, straw and grain yields of wheat were observed in wheat + canola intercropping system as com-

Table 1. Climatic parameters during 2012–13 and 2013–14

Month	2012–13					2013–14				
	Rainfall (mm)	Rainy days	Maximum temperature (ºC)	Minimum temperature (ºC)	Average temperature (ºC)	Rainfall (mm)	Rainy days	Maximum temperature (ºC)	Minimum temperature (ºC)	Average temperature (ºC)
October	0.0	–	31.6	16.2	23.9	36.2	2	31.4	20.2	25.8
November	0.0	–	26.6	10.5	18.6	4.6	1	26.7	10.1	18.4
December	17.4	2	19.4	7.4	13.4	28.0	2	20.0	7.4	13.7
January	8.2	1	17.0	5.1	11.1	55.5	3	17.5	7.0	12.2
February	96.4	8	20.5	9.7	15.1	36.7	3	19.4	8.2	13.9
March	35.6	2	27.6	13.2	20.4	35.0	5	25.3	12.5	18.9
April	4.4	1	34.2	18.3	26.3	31.0	2	32.7	16.7	24.7
Total	162.0	13	–	–	–	227.0	18	–	–	–

Table 2. Effect of different intercropping systems and levels of nutrients applied to intercrops on yield attributes of wheat (pooled data of 2 years)

Treatment	Ears/m row length	Grains/ ear	Ear length (cm)	Ear weight (g)	1,000-seed weight (g)
Intercropping system					
Wheat + spinach	82.6	60.0	11.4	2.7	42.9
Wheat + fenugreek	81.7	59.7	11.0	2.6	42.7
Wheat + fodder oats	78.8	57.5	10.9	2.6	42.2
Wheat + canola	74.4	55.9	10.7	2.5	40.5
Wheat + linseed	77.9	57.1	10.8	2.5	41.4
SEm±	1.3	0.8	0.1	0.4	0.9
CD (P=0.05)	4.2	2.7	NS	NS	NS
Recommended dose of nutrients to intercrop (i.e.)					
0%	77.6	56.5	10.6	2.4	40.6
50%	78.5	57.8	10.9	2.6	41.3
75%	79.8	58.6	11.1	2.6	42.5
100%	80.5	59.3	11.4	2.7	43.3
SEm±	1.1	0.7	0.1	0.4	0.8
CD (P=0.05)	NS	NS	NS	NS	NS

NS, Non-significant

pared to other intercropping systems, it is because of in intercropping system, canola was more exposed to the Sun and wheat suffered more as it was growing under the canola canopy. Similar findings also reported by Khan *et al*., (2005) and Kumar (2008). Biological, straw and grain yields of wheat were not significantly influenced by the different levels of nutrients applied to intercrops (Table 3), which may be attributed to fact that wheat crop sown in raised bed and fertilized with 100% recommended dose of nutrients, whereas different levels of recommended dose of nutrients to intercrops were applied in furrows. Because of this competition between wheat and the component crops for the resources like water, nutrients, space and sunlight were minimum and there was non-competitive or complimentary effect of different doses of nutrients applied to the intercrops on the performance of wheat. Harvest index and grain: straw ratio were not affected significantly in relation to the intercropping systems and different levels of nutrients applied to intercrops.

With the increased dose of nutrients from 0 to 100% applied to the intercrops on area basis resulted progressive increase in yield of intercrops (Table 3). This may be attributed to the greater availability of nutrients at higher rate of fertilizer application, which in turn increased the yield of the intercrops.

Wheat-equivalent yield and system productivity

Wheat-equivalent yield was affected significantly by the intercropping systems and levels of nutrients applied to the intercrops. Among the intercropping systems, wheat + fodder oats (6.64 t/ha) intercropping system resulted in significantly highest wheat-equivalent yield followed by wheat + spinach followed by wheat + canola intercropping system. Fodder oats is a fast-growing crop, having higher yield potential, short duration and less competitive than canola and linseed. Spinach and fenugreek were also short duration, less competitive than fodder oats but their yield potential was less as compared to the fodder oats in intercropping system. So, the wheat-equivalent yield of wheat + fodder oats intercropping system was significantly higher than the other intercropping systems. There were significant effects of different levels of nutrients applied to intercrops on wheat-equivalent yield. The data revealed that with increased dose of nutrients from 0 to 100% applied to intercrops on area basis, there was progressive increase in wheat-equivalent yield. Average of 2 years data revealed that application of 100% recommended dose of nutrients to the intercrops resulted in significantly higher wheat-equivalent yield (6.26 t/ha) than the 75% recommended dose of nutrients to the intercrops (6.07 t/ha), which was higher than 50% recommended dose of nutrients to the intercrops (5.88 t/ha) and control plots (5.72 t/ha) (i.e. nutrients was not applied to the intercrops). Similar trend was observed for system productivity. Among the intercropping systems, wheat + fodder oats (41.8 kg/ha/day) intercropping system revealed significantly higher system productivity than the other wheat-based intercropping systems during both the growing seasons. The application of 100% recommended dose of nutrients to the intercrops resulted in significantly higher value of system productivity (39.3 kg/ha/day) than the other levels of nutrients applied to the intercrops on area basis.

Table 3. Effect of different intercropping systems and levels of nutrients applied to intercrops on biological, grain and straw yields of wheat and yield of intercrops (pooled data of 2 years)

Treatment	Biological yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Grain: straw ratio	Intercrop yield (t/ha)
Intercropping system						
Wheat + spinach	12.17	5.40	6.77	44.4	0.80	3.10
Wheat + fenugreek	12.01	5.29	6.72	44.1	0.79	1.21
Wheat + fodder oats	11.74	5.12	6.61	43.7	0.78	13.63
Wheat + canola	10.39	4.74	5.64	45.7	0.84	0.52
Wheat + linseed	11.37	5.07	6.29	44.7	0.82	0.21
SEm±	0.16	0.08	0.13	0.8	0.03	
CD (P=0.05)	0.53	0.30	0.43	NS	NS	–
Recommended dose of nutrients to intercrop (i.e.)						
0%	11.39	5.05	6.36	44.3	0.80	3.11
50%	11.48	5.08	6.37	44.6	0.81	3.63
75%	11.59	5.15	6.43	44.6	0.81	3.98
100%	11.68	5.21	6.46	44.7	0.81	4.21
SEm±	0.11	0.05	0.11	0.6	0.02	
CD (P=0.05)	NS	NS	NS	NS	NS	–

NS, Non-significant

Table 4. Effect of intercropping systems and levels of nutrients applied to intercrops on wheat-equivalent yield, system productivity and economic returns of bed-planted wheat (pooled data of 2 years)

Treatment	Wheat-equivalent yield (t/ha)	System productivity (kg/ha/day)	Gross returns (× 10^3 /ha)	Net returns (× 10^3 /ha)	Benefit : cost ratio
Intercropping system					
Wheat + spinach	6.18	38.8	99.3	65.6	1.94
Wheat + fenugreek	5.69	35.8	92.4	58.4	1.72
Wheat + fodder oats	6.64	41.8	105.5	71.4	2.09
Wheat + canola	5.81	36.5	94.3	56.9	1.52
Wheat + linseed	5.60	35.2	90.3	54.8	1.54
SEm±	0.09	0.6	1.3	1.2	0.03
CD (P=0.05)	0.29	1.8	4.1	4.3	0.09
Recommended dose of nutrients to intercrop (i.e.)					
0%	5.72	36.0	92.6	58.1	1.70
50%	5.88	37.0	94.9	60.0	1.72
75%	6.07	38.2	97.7	62.6	1.79
100%	6.26	39.3	100.3	65.0	1.85
SEm±	0.06	0.4	0.8	0.7	0.02
CD (P=0.05)	0.15	1.0	2.2	2.1	0.05

Economics

Wheat + fodder oats intercropping system resulted in significantly higher value of gross returns (₹105,500) than the other wheat-based intercropping systems, followed by wheat + spinach (₹99,300) followed by wheat + canola (₹94,300) intercropping system. There were significant effects of different levels of nutrients applied to intercrops on gross returns. With the increased dose of nutrients from 0 to 100% applied to intercrops on area basis, there was progressive increase in gross returns. The lowest value of gross returns was recorded in control plots, i.e. nutrients were not applied to the intercrops, which were increased significantly with the increased levels of nutrients applied to intercrops. The application of 100% recommended dose of nutrients to the intercrops resulted in significantly higher value of gross returns (₹100,300) than the 75% recommended dose of nutrients to the intercrops (₹97,700) which was higher than the 50% recommended dose of nutrients to the intercrops (₹94,900) and the control plots (₹92,600) (i.e. nutrients was not applied to the intercrops) (Table 4). Wheat + fodder oats intercropping system resulted in significantly higher value of net returns (₹71,400), followed by wheat + spinach (₹65,600) than the rest of the wheat-based intercropping systems. Application of 100% recommended dose of nutrients to the intercrops resulted in significantly higher value of net returns (₹65,000) than the other recommended dose of nutrients applied to the intercrops on area basis (mean of 2 years data). Among the intercropping systems wheat + fodder oats (2.09) showed significantly higher value of benefit: cost ratio than the other wheat-based intercropping systems. The 100% recommended dose of nutrients to the intercrops resulted in significantly higher value of benefit cost ratio (1.85) than the other recommended dose of nutrients applied to the intercrops on area basis (Table 4).

It was concluded that wheat + fodder oats intercropping system gave significantly higher wheat-equivalent yield, system productivity and the economic returns followed by wheat + spinach intercropping system than the other intercropping systems. With the increased dose of nutrients from 0 to 100% applied to intercrops on area basis, there was progressive increase in yield of intercrops. The application of 100% recommended dose of nutrients to the intercrops resulted in significantly higher value of wheat-equivalent yield, system productivity and economic returns than the other recommended dose of nutrients applied to the intercrops.

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