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Performance of cropping systems based on winter maize (*Zea mays*) under irrigated condition

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ABSTRACT

A field experiment was carried out at Ludhiana during 1987–88 to 1990–91 to evaluate the production potential of 10 winter maize (*Zea mays* L.)-based cropping systems. Winter maize gave higher grain yield of 4 994 and 4 712 kg/ha when raised after groundnut (*Arachis hypogaea* L.) and pigeonpea [*Cajanus cajan* (L.) Millsp.] respectively, but gave low yield (4 023 kg/ha) after rice (*Oryza sativa* L.). Winter maize (transplanted) after potato (*Solanum tuberosum* L.) gave significantly higher grain yield (4 380 kg/ha) than when it followed *toria* [*Brassica rapa* (L.) Thell. emend. Metzger var *napus* L.; syn *Brassica campestris* L. ssp *oleifera* (Metzger) Sinsk. var toria]. On calculation the winter maize (transplanted)–pearl millet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz] for fodder–potato system gave the highest winter maize-equivalent yield (29.67 tonnes/ha), gross income (Rs 65 263/ha), net income (Rs 27 340/ha) and productivity efficiency (102.3 kg/ha/day). Winter maize–greengram (*Phaseolus radiatus* L.) or sunflower (*Helianthus annuus* L.) system gave low winter maize- equivalent yield (5.7 and 6.9 tonnes/ha) and gross income (Rs 12 506 and 15 180/ha), and resulted in a loss of Rs 2 225 and 2 283/ha respectively. Land-use efficiency was highest (93.9%) in winter maize–pigeonpea, followed by winter maize–groundnut and was lowest in wheat (*Triticum aestivum* L. emend. Fiori & Paol.)–maize. Cropping system having legume or potato as one of the components increased the organic carbon and available P and K status of the soil.

Researches carried out at Punjab Agricultural University, Ludhiana, have made it possible to cultivate maize (*Zea mays* L.) during winter. There is need to increase the area under winter maize to sustain dairy and poultry farming, because it is an important ingredient in animal feed. Maize during winter has higher yield potential than wheat (*Triticum aestivum* L. emend. Fiori & Paol.) and can help in much-needed diversification of wheat-dominated cropping pattern. Winter maize can be transplanted up to mid-January and thus it can replace the late-sown wheat Khehra *et al.* (1990). Sidhu *et al.* (1993) reported that rice (*Oryza sativa* L.) yield was the highest in rice–potato (*Solanum tuberosum* L.)–winter maize (transplanted) system and the lowest in rice–wheat. Hence an experiment was conducted to investigate the production potential of winter maize-based cropping systems in relation to sustainability of productivity of the cropping system and soil health.

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MATERIALS AND METHODS

The field experiment was conducted from 1987–88 to 1990–91 in fixed plots at Ludhiana. Ten cropping systems involving winter maize as a hub crop in sequence were: T_1, 'Partap 1' winter maize–'Partap 1' maize; T_2, 'Partap 1' winter maize–'ML 267' greengram (*Phaseolus radiatus* L.); T_3, 'Partap 1' winter maize–'PK 416' soybean [*Glycine max* (L.) Merr.]; T_4, 'Partap 1' winter maize (transplanted)–local maize + cowpea (fodder) [*Vigna unguiculata* (L.) Walp.]–'TL 15' *toria* [*Brassica rapa* (L.) Thell. emend. Metzger var *napus* L.; syn *B. campestris* L. ssp *oleifera* (Metzger) Sinsk. var toria]; T_5, 'Partap 1' winter maize (transplanted)–local pearl millet (fodder) [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz]–'Kufri Chandramukhi' potato; T_6, 'Partap 1' winter maize–'MSFH 8' sunflower (*Helianthus annuus* L.); T_7, 'Partap 1' winter maize–'PR 106' rice; T_8, 'Partap 1' winter maize–'AL 15' pigeonpea [*Cajanus cajan* (L.) Millsp.]; T_9, 'Partap 1' winter maize–'M 335' groundnut (*Arachis hypogaea* L.); and T_{10}, 'Partap 1' rainy-season maize–'WL 711' wheat. The cropping systems were laid out in randomized block design with 4 replications. The soil was sandy loam, having 0.20% organic carbon, and 18 and 150 kg/ha available P and K respectively. All the crops were grown with inputs as per recommendation, except sunflower which was grown on residual nutrients left by potato crop. Winter maize was directly sown during the second week of November, transplanted in the first week of January and harvested during the last week of May. For transplanted maize, maize seedlings at 50–60 days were transplanted on southern slope of east-west ridges and irrigated immediately after transplanting, followed by another irrigation after a week. The sowing time of maize + cowpea (fodder), pearl millet (fodder), pigeonpea, soybean and groundnut was the second fortnight of June; of rainy-season maize, greengram and rice the first fortnight of July; of sunflower the second fortnight of July; of *toria* from 7–23 September; and of potato 9–25 October. Maize + cowpea (fodder) and pearl millet (fodder) were harvested during 8–29 August, greengram in the second fortnight of September, rainy-season maize and rice in the first fortnight of October, soybean and groundnut in the second fortnight of October, pigeonpea in the first fortnight of November, *toria* in the second fortnight of December, potato in first week of January and wheat in the first fortnight of April during all the 4 years. Gross and net returns from each system were calculated on the basis of prevailing market prices during 1991–92. The gross income of different crops was converted into maize equivalents by dividing with maize price to compare the production potential of different cropping systems. Land-use efficiency and production efficiency were worked out. The surface soil samples (0–15 cm) from each cropping system were collected during June 1991 after completion of 4 cycles of crops and analysed for organic carbon, P and K (Jackson 1973).

RESULTS AND DISCUSSION

Winter maize

The grain yield of winter maize during 4 years showed that it could be raised successfully during winter by direct sowing after the rainy-season (*kharif*) crops of maize, greengram, soybean, sunflower, rice, pigeonpea and groundnut and by transplanting after maize + cowpea (fodder)–*toria* and pearl millet (fodder)–potato systems (Table 1). The preceding leguminous crops had beneficial effect on growth and grain yield of winter maize, and the highest grain yield (4 994 kg/ha) was obtained after groundnut. This might be attributed to better fixation of atmospheric nitrogen in the soil and increase in

Table 1 Yield of different crops, maize equivalents, gross income, variable cost, net income, production efficiency and land-use efficiency of winter maize-based cropping systems (mean data of 4 years)

Cropping system	Yield of crops (kg/ha)			Maize equivalent (tonnes/ha)	Gross income (Rs/ha)	Variable cost (Rs/ha)	Net income (Rs/ha)	Production efficiency (kg/day/ha)	Land-use efficiency (%)	Duration of system (days)
	I	II	III							
T_1	4 144	2 733		8.98	19 758	18 433	1 325	30.4	80.8	295
T_2	4 168	278		5.70	12 506	14 731	—2 225	20.9	74.2	271
T_3	4 685	1 697		9.13	20 098	14 881	5 217	28.3	88.5	323
T_4	3 222	30 560	1 377	11.08	24 393	23 706	687	35.3	86.0	314
T_5	4 380	54 050	21 355	29.67	65 263	37 923	27 340	102.3	79.4	290
T_6	4 456	566		6.90	15 180	17 463	—2 283	24.8	76.2	278
T_7	4 023	4 787		9.92	21 824	19 428	2 396	33.4	81.4	297
T_8	4 712	1 182		9.60	21 118	14 063	7 055	27.9	93.9	343
T_9	4 994	960		9.23	20 300	18 558	1 742	28.1	89.8	328
T_{10}	2 756	4 393		9.26	20 366	15 265	5 101	37.3	67.9	248
CD ($P = 0.05$) (maize)	939									

T_1, Winter maize–rainy-season maize; T_2, winter maize–greengram; T_3, winter maize-soybean; T_4, winter maize (transplanted)–maize + cowpea (fodder)-*toria*; T_5, winter maize (transplanted)–pearl millet (fodder)–potato; T_6, winter maize–sunflower; T_7, winter maize–rice; T_8, winter maize–pigeonpea; T_9, winter maize–groundnut; T_{10}, rainy-season maize–wheat

organic carbon content (Table 2). Sidhu *et al.* (1990) reported increase in inorganic carbon when a legume preceded the wheat crop. Winter maize is known for its response to nitrogen up to 240 kg N/ha. De *et al.* (1983) and Narwal and Malik (1987) also reported beneficial effect of preceding legumes on grain yield of rice and wheat respectively. Direct-sown winter maize gave the lowest yield (4 023 kg/ha) after rice. Transplanted winter maize gave significantly more yield when it followed potato (4 350 kg/ha) compared with that after *toria* (3 222 kg/ha). This increase in yield might be attributed to the sufficient nutrients left in the soil after potato, which was fertilized heavily and being of short duration could not absorb all the nutrients. Singh (1977) reported build up of medium status of N, P and K from initial low status in rotations having potato as one of the crops.

Rainy-season crops

Rice performed better (4 787 kg/ha) than rainy-season maize (2 756 kg/ha) during all the 4 years, as the latter during monsoon is sensitive to both high as well as low water stress (Table 1). Among the various pulse crops, soybean gave the higher yield than greengram and pigeonpea. Sidhu *et al.* (1992) also reported poor performance of sunflower. Groundnut gave reasonably good pod yield. The fodder crops of maize + cowpea and pearl millet gave 30.6 and 54.0 tonnes/ha respectively. Pearl millet proved better than maize because of its quick growth and tillering habit.

Gross return

Gross return was the highest from winter maize (transplanted)–pearl millet (fodder)–potato system (22.0%), followed by winter maize (transplanted)–maize + cowpea (fodder)–*toria* (19.7%) in comparison with the traditional maize–wheat system. Winter maize–greengram gave the lowest gross income (Rs 11 659/ha) because of poor performance of greengram due to rains during early stages of growth. The same trend was observed for productivity calculated in the terms of winter maize-equivalent yield (Table 1) of various cropping systems. The higher productivity in these 2 cropping systems could be attributed to better performance of pearl millet and maize + cowpea as fodder, and inclusion of short-duration crops of potato or *toria* between the main crops. A heavily-fertilized potato crop leaves considerable nutrient residue to have beneficial effect on winter maize. Expenditure on inputs was the highest (Rs 37 923/ha) in winter maize–pearl millet (fodder)–potato, followed by winter maize (transplanted)–maize + cowpea (fodder)–*toria* and lowest in winter maize–pigeonpea system (Table 1).

Net return

Winter maize (transplanted)–pearl millet–potato and winter maize–pigeonpea gave 436 and 38% more net returns than the traditional rotation of maize–wheat. Winter maize–soybean was at par with maize–wheat rotation for net return. However, all other cropping systems recorded less net return than maize–wheat. Two rotations of winter maize with greengram and sunflower gave less return, resulting in 15 and 13% loss due to poor performance of the latter 2 crops during rainy season.

Production efficiency

Production efficiency was the highest from winter maize (transplanted)–pearl millet (fodder)–potato system, followed by maize–wheat (Table 1). It was the lowest in greengram–winter maize.

Land-use efficiency

Land-use efficiency was the highest in winter maize–pigeonpea cropping system,

followed by winter maize–groundnut (89.9), which could be due to their long duration (Table 1). The lowest land-use efficiency in maize–wheat system indicated the scope to introduce third crop in between them. Land-use efficiency was lower (79.5) in winter maize (transplanted)–pearl millet (fodder)–potato system than that of 86.1 in winter maize (transplanted)–maize + cowpea (fodder)–*toria* because of short duration of potato and pearl millet (fodder) crops and late maturity of *toria* and long time taken by maize + cowpea (fodder) to be ready for harvest.

Change in nutrient status of soil

In general, there was increase in organic content after completion of 4 cycles of crops compared with the initial status (0.20%) in all the cropping systems except winter maize–rice and winter maize (transplanted)–maize + cowpea (fodder)–*toria* (Table 2). However, cropping systems having legume as one of the components showed an increase in organic carbon compared with cereal–cereal systems. The result confirms the finding of Tomar and Tiwari (1990). The available P content increased in all the cropping systems and maximum available P (27 kg/ha) was found in winter maize (transplanted)–pearl millet–potato compared with 18 kg/ha at the beginning of the experiment (Table 2). The increase in P content in the soil in this rotation might be attributed to potato crop, which was fertilized heavily. The highest content of available K was recorded in winter maize (transplanted)–pearl millet–potato system compared with the initial status of 150 kg/ha. There was slight increase in K content in all other cropping systems except winter maize (transplanted)–maize + cowpea (fodder)–*toria*, winter maize–sunflower and winter maize–rice systems. Sharma *et al.* (1987) also reported increase in P and K contents after potato crop.

Table 2 Status of available nutrients in soil after 4 cycles of crops as affected by winter maize-based cropping systems

Cropping system	Organic C (%)	P (kg/ha)	K (kg/ha)
T_1	0.22	20	161
T_2	0.21	21	162
T_3	0.23	22	165
T_4	0.19	22	145
T_5	0.20	27	174
T_6	0.22	20	146
T_7	0.19	17	140
T_8	0.24	20	155
T_9	0.24	18	162
T_{10}	0.20	20	152
Initial soil status	0.20	18	150

Details of treatments are given under Table 1

Winter maize (transplanted)–pearl millet (fodder)–potato, winter maize–pigeonpea and winter maize–soybean systems have the potential to replace prevalent cereal–cereal system of maize–wheat.

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