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Research Paper

Performance of Pulse and Non-pulse Crop Rotations at Small Farms Under Irrigated Conditions of Punjab

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A B S T R A C T

Data was collected during 2014-15 and 2015-16 from 100 small farmers of 10 villages from randomly selected Amritsar and Gurdaspur districts of Punjab, India, to evaluate the performance of various pulse based crop rotations viz. rice-wheat-summer moong (summer pulse crop rotation (SPCR1)), arhar-wheat (main pulse crop rotation (MPCR2)), rice-lentil (main pulse crop rotation (MPCR3)), arhar-lentil (pulse-pulse crop rotation (PPCR4) compared to the existing rice-wheat cropping system as non-pulse crop rotation (NPCR5). Rice equivalent yield, crop productivity, system productivity and land use efficiency was recorded significantly higher in SPCR1 (12.99 t/ha, 36.76 kg/ha/day, 35.59 kg/ha/day and 96.66%) compared to NPCR5 (9.94 t/ha, 33.65 kg/ha/day, 27.22 kg/ha/day and 80.81%), MPCR2 (8.77 t/ha, 29.86 kg/ha/day, 24.08 kg/ha/day and 80.52%), MPCR3 (8.74 t/ha, 30.99 kg/ha/day, 23.95 kg/ha/day and 77.40%) and MPCR4 (6.69 t/ha, 24.66 kg/ha/day, 18.84 kg/ha/day and 76.21%) respectively. The inclusion of main season pulse crops in crop rotations helped to reduce the quantity of irrigation and application of chemical nutrients significantly compared to existing rice-wheat crop rotation and recorded significantly lower in PPCR4 (17.52 ha-cm and 76 kg/ha) compared to all other pulse and non-pulse crop rotations. AWUP and ANUP were recorded significantly higher in PPCR4 (437.65 and 89.74 kg/ha) than all other crop rotations. Inclusion of summer pulse in existing rice -wheat cropping system helped to enhance crop productivity and system productivity (9.24% and 30.75%) over rice- wheat alone which was otherwise recorded better in crop productivity and system productivity than all other crop rotations selected for study under irrigated conditions of Punjab.

***Key words*:** Crop productivity, Land use efficiency, Rice equivalent yield, System productivity, Crop rotation

The green revolution was introduced in India during late sixties as a milestone in Indian agriculture which transformed the country from stage of food deficiency to self-sufficiency. The production of food grain has increased more than two folds from 108.4 MT in 1970-71 to 275.68 MT in 2018-19 [1]. The major portion of food grain production is contributed by cereals of which rice-wheat cropping system contributes to the maximum i.e. 110.2 and 98.4 MT respectively during 2016-17. The average productivity of total food grains increased from 872 kg/ha in 1970-71 to 2153 kg/ha in 2018-19 [2] was a result of increase in the cultivated area, expansion in irrigated area and the use of high-yielding varieties which witnessed a change in the entire agricultural systems of the country. The low productive risk prone legumes and oil seed crops were diverted on marginal and fragile lands of dry areas whereas the cereal based multiple cropping systems covered irrigated areas in North. Area under pulse crop cultivation increased from 13.92 m ha in 1971-75 to 16.22 m ha in 2005-06 in states like Andhra Pradesh, Rajasthan, Gujarat, Karnataka, Maharashtra, Madhya Pradesh and Tamil Nadu whereas Bihar, Haryana, Punjab, Uttar Pradesh, West Bengal and Orissa witnessed the reverse trend with declining in area from 8.0 m ha to 4.6 m ha during the same period [1]. The situation of food basket (Punjab) of India needs immediate attention because of the over dependence on rice- wheat cropping system. In Punjab, rice – wheat crop rotation covers about 83 per cent of the cultivable area of the state with 199 per cent cropping intensity have led to crisis in terms of over exploitation of natural resources, environment and health issues of which water was severely affected. Out of 22 districts of the state about 14 districts are under no water zone with fall of underground water table to a dangerous level of 25 meters or below and out of 150 blocks of the state 44 blocks fall under this dangerous zone [2]. Apart this, declining productivity, lower fertilizer response ratio, degradation of soil health and declining profitability of cultivation are some other fore fronts of the Punjab agricultural problems. Majority of the farmers in Punjab state are of small in nature with less than two hectares of cultivable land and with limited resources. As a large section of Indian population is vegetarian and to address the growing protein requirement has ultimately increased annual import of pulses to 57.98 lakh tonnes worth Rs. 25619.06 crore against the import value of Rs. 26841.87 crore for total food grains, Rs. 140288.69 crore for total agricultural import and Rs. 2490298.08 crore for total National import respectively during 2017-18 [3]. More over the contribution of Punjab in pulse crop production, area and yield of 0.46 (0.25% of the country), 0.53 (0.21 % of the

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country) and 871 kg/ha under area which is very small and negligible compared to other states of India. Therefore, the present study was under taken to address the above listed problems and to enhance production and productivity of small farms of Punjab in the year 2014 and 2015.

MATERIALS AND METHODS

The study was conducted on the basis of survey conducted in Punjab, India. Data was collected from 120 small farms of 10 villages selected from two blocks of each district i.e. Amritsar and Gurdaspur (selected randomly from major pulse growing districts of Punjab i.e. Amritsar, Tarn Taran, Gurdaspur, Ludhiana, Patiala and Hoshiarpur), to make the sample size. Five pulse and non-pulse based crop rotations i.e. Rice-wheat-summer moong (summer pulse crop rotation (SPCR1)), Arhar-Wheat (main pulse crop rotation (MPCR3)), Rice-lentil (main pulse based crop rotation (MSPCR4)), Arhar-lentil (pulse-pulse crop rotation (PPCR5) and Rice-wheat as (non-pulse crop rotation (NPCR6)) were selected to evaluate production, productivity and resource use efficiency of various pulse and non-pulse based crops. The yield data of various crops was converted to rice equivalent yields using following formula:

$$\text{Rice equivalent yield (kg/ha)} = \frac{\text{Component crop yield (kg/ha)}}{\text{Price of rice crop (of NPBCR5 (Rs/kg))}} \times \text{Price of the component crop (Rs/kg)}$$

The statistical analysis was done by using statistical techniques described by [4]. Various productivity indices such as crop productivity, system productivity, land use efficiency, apparent water use potential (AWUP) and apparent nutrient use potential (ANUP) were calculated as suggested by [5], [6] with following formulae:

$$\text{Crop productivity (kg/ha/day)} = \frac{\text{Rice equivalent yield of the system (kg/ha)}}{\text{Number of days taken by crops of the system in the field}}$$

$$\text{System productivity (kg/ha/day)} = \frac{\text{Rice equivalent yield of the system (kg/ha)}}{365 \text{ days}}$$

$$\text{Land use efficiency (\%)} = \frac{\text{Number of days taken in the field by crops in a system}}{365} \times 100$$

$$\text{Apparent water use potential (AWUP (kg/ha))} = \frac{\text{Rice equivalent yield of the system (kg/ha)}}{\text{Total irrigations (ha cm)}}$$

$$\text{Apparent nutrient use potential (ANUP (kg/ha))} = \frac{\text{Rice equivalent yield of the system (kg/ha)}}{\text{Total nutrients (NPK) used (kg/ha)}}$$

To convert the number of irrigations in ha-cm the total number of irrigations for respective crops were multiplied with constant number 5 for rice crop and 7.3 for all other crops selected in various pulse and non-pulse based crop rotations.

RESULTS AND DISCUSSION

Rice equivalent yield

Average data of two years indicated that rice equivalent yield (Table 1) in SPCR1 (12.99 t/ha) was significantly higher than all other crop rotations selected for study followed by NPCR5 (9.94 t/ha) which was also recorded significantly higher rice equivalent yield than rest of the crop rotations. Rice equivalent yield in MPCR2 (8.77 t/ha) and MPCR3 (8.74 t/ha) were observed statistically at par but witnessed significantly higher than PPCR4 (6.69 t/ha). This increase may be due to inclusion of pulse crops which have the property to fix atmospheric nitrogen in soil and helps to extract the nutrients from the deeper layers of the soil which was also concluded by [7], [8]. The inclusion of moong bean in rice-wheat cropping system increased the total productivity of the system was also confirmed by [9], [10].

Number of days

Less number of days taken (Table 1) by various crops in a cropping system was considered beneficial to enhance the productivity per unit area over those, took more number of days in the field. Completion of a cropping system in lesser days also helps in early vacation of field for timely completion of sowing and harvesting operations and better management of existing cropping rotations. Among various selected crop rotations, PPCR4 (278.17) recorded significantly lower number of days compared to all other crop rotations selected for the study followed by MPCR3 (282.50). Numbers of days taken by crops in the field were statistically at par in MPCR2 (293.80) and NPCR5 (294.95) but significantly lower than CPCR1 (352.82). Crops in SPCR1 (352.82) took significantly higher number of days as compare to all other crop rotations. The similar observations were also recorded in the [11].

Crop productivity (kg/ha/day)

Crop productivity was found significantly higher in SPCR1 (36.76 kg/ha/day) compared to all other crop rotations selected for the present study followed by NPCR5 (33.65 kg/ha/day) which was also found significantly higher than MPCR3 (30.99 kg/ha/day), MPCR2 (29.86 kg/ha/day) and PPCR4 (24.66 kg/ha/day). Crop productivity was recorded statistically at par between MPCR3 (30.99 kg/ha/day) and MPCR2 (29.86 kg/ha/day) but recorded significantly higher than PPCR4 (24.66 kg/ha/day). Crop productivity was witnessed significantly lower in PPCR4 (24.66 kg/ha/day) compared to all other crop rotations selected for the study. Crop productivity indicates productivity during crop days in the field in a particular crop rotation. Higher crop productivity of a particular cropping system indicates its superiority over those with lower crop productivity was also confirmed by [12], [13], [14].

System productivity (kg/ha/day)

System productivity is an indicator of high production and productivity among various cropping systems. Crop rotations with higher system profitability were considered better over the other with less system productivity. The system productivity was found significantly higher in SPCR1 (35.59 kg/ha/day) compared to all other crop rotations selected for study. System productivity in NPCR5 (27.22 kg/ha/day) was significantly lower than SPCR1 (35.59 kg/ha/day) but observed significantly higher than MPCR2 (24.08 kg/ha/day), MPCR3 (23.95 kg/ha/day) and PPCR4 (18.81 kg/ha/day) with and per cent respectively. System productivity was observed

statistically at par with each other but significantly higher than PPCR4 (18.81 kg/ha/day). Significantly lower system productivity was registered in PPCR4 compared to all other crop rotations. Improvement in system productivity with inclusion of summer moong in rice- wheat cropping system was also reported by [15], [16].

Table 1 Productivity of pulse and non-pulse based crop rotation at small farms of Punjab

Particulars	2014-15				2015-16				Mean 2014-16			
	1	2	3	4	1	2	3	4	1	2	3	4
SPCR1	11.57	349.41	33.09	31.70	14.41	356.23	40.43	39.48	12.99	352.82	36.76	35.59
MSPCR2	7.92	290.30	27.25	21.69	9.63	297.30	32.37	26.39	8.77	293.80	29.86	24.08
MSPCR3	8.05	289.10	27.82	22.05	9.43	275.90	34.17	25.84	8.74	282.50	30.99	23.95
PPCR4	5.91	277.12	21.29	16.20	7.84	279.22	28.04	21.49	6.69	278.17	24.66	18.84
NPCR5	9.38	293.60	31.91	25.69	10.50	296.30	35.38	28.75	9.94	294.95	33.65	27.22
CD (0.05)	-	-	-	-	-	-	-	-	0.47	2.95	1.32	1.30

1. Rice equivalent yield (kg/ha); 2. Crop productivity (kg/ha); 3. System productivity (kg/ha); 4. Rice equivalent yield (kg/ha)

Table 2 Comparative land, water and NPK use in various pulse and non-pulse based crop rotations at small farms of Punjab

Particulars	2014-15					2015-16					Mean (2014-16)				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
SPCR1	95.73	174.35	66.49	371.57	31.12	97.60	166.53	86.65	388.87	37.03	96.66	170.44	76.57	380.22	34.07
MSPCR2	79.53	51.46	156.00	207.47	38.13	81.45	50.37	196.63	194.25	49.53	80.52	47.19	188.58	187.02	46.86
MSPCR3	79.21	108.76	74.00	200.35	40.12	75.59	117.30	80.33	217.15	43.39	77.40	113.03	77.16	208.75	41.75
PPCR4	75.92	18.98	356.50	68.18	86.20	76.50	16.06	518.81	83.82	93.28	76.21	17.52	437.65	76.00	89.74
NPCR5	80.44	170.26	55.10	364.52	25.70	81.18	169.05	62.07	386.48	27.12	80.81	169.66	58.58	375.50	26.41
CD (0.05)	-	-	-	-	-	-	-	-	-	-	0.81	4.9	35.88	4.55	2.04

1. Land use efficiency (%); 2. Irrigation (ha cm); 3. AWUP; 4. NPK (kg/ha); 5. ANUP

Land use efficiency (LUE)

Land use efficiency was recorded significantly higher in SPCR1 (96.66%), compared to all other crop rotations selected for the study. LUE was registered statistically at par in NPCR5 (80.81%) and MPCR2 (80.52%) but significantly higher than MPCR3 (77.40%) and PPCR4 (76.21%). MPCR3 (77.40%) and PPCR4 (76.21%) were also found statistically at par in LUE. Higher LUE primarily indicates increase in intensity in a particular cropping system over those with lower was concluded by [17].

Number of irrigations

Minimum water was supplied in PPCR4 (17.52 ha cm) compared to all other crop rotations selected for study at small farms of Punjab. Irrigation water in MPCR2 (47.19 ha cm) was recorded significantly lower than MPCR3 (113.03 ha cm) and SPCR1 (170.44 ha cm) and NPCR5 (169.66 ha cm). Water use was also observed significantly lower in MPCR3 (113.03 ha cm) compared to NPCR5 (169.66 ha cm) and SPCR1 (170.44 ha cm) which were recorded statistically at par with each other. Similar results about limited use of water in pulse-based crop rotations compared to non-pulse were also endorsed by [18].

Apparent water use productivity (AWUP)

The water is becoming a major concern in Punjab since last three decades and keeping in view the future needs and availability of water, per drop management of water is the need of the hour. The higher AWUP indicates more efficient use of water in a particular system over those with minimum AWUP. Among various crop rotations selected for the study, AWUP was recorded significantly higher in PPCR4 (437.65 kg/ha cm) followed by MPCR2 (188.58 kg/ ha cm) whereas all other crop rotations viz. MPCR3 (77.16 kg/ha cm), SPCR1 (76.57 kg/ha cm) and NPCR5 (58.58 kg/ha cm), were witnessed AWUP as statistically at par to each other [19].

Use of chemical fertilizers (NPK)

The more use of chemical nutrients deteriorates the soil conditions to a large extent. All the selected crop rotations vary significantly in the use of chemical fertilizers among each other. The uses of NPK in terms of chemical fertilizers were significantly lower in PPCR4 (76 kg NPK/ha) followed by MPCR2 (187.02 kg NPK/ha), MPCR3 (208.75 kg NPK/ha) and NPCR5 (375 kg NPK/ha). The use of NPK was recorded significantly higher in SPCR1 (380.22 kg NPK/ha) compared to all other crop rotations [20].

Apparent nutrient use productivity (ANUP)

The better utilization of nutrients per unit of production in a particular cropping system was considered beneficial over the other. In present investigations, all crop rotations vary significantly among each other for ANUP. ANUP was observed significantly higher in PPCR4 (89.74 kg/ha/kg NPK) followed by MPCR2 (46.86 kg/ha/kg NPK), MPCR3 (41.75 kg/ha/kg NPK), SPCR1 (34.07 kg/ha/kg NPK) and NPCR5 (26.41 kg/ha/kg NPK). All the crop rotations with inclusion of pulse crops (either in main season or in summer season) were witnessed significantly better ANUP than those without any pulse crop (NPCR5). Increase in yield and efficient use of NPK was also evaluated by [21].

CONCLUSIONS

The inclusion of pulse crops in the prevalent crop rotations were observed better as compared to non-pulse based crop rotations. Inclusion of summer pulse in existing rice - wheat cropping system helped to enhance crop productivity and system productivity (9.24% and 30.75%) over rice- wheat alone which was otherwise recorded better in crop productivity and system productivity under irrigated conditions of Punjab. The investigations of the present study indicate that rice equivalent yield was recorded significantly

higher in SPCR1 (12.99 t/ha) compared to other pulse and non-pulse crop rotations. Crop productivity and system productivity was observed significantly higher in SPCR1 (12.99 t/ha) followed by NPCR5 (9.94 t/ha), MPCR2 (8.77 t/ha), MPCR3 (8.74 t/ha) and PPCR4 (6.69 t/ha). Land use efficiency was registered significantly higher in SPCR1 (12.99 t/ha) compared to other pulse and non-pulse crop rotations in the study. Minimum numbers of irrigations and higher AWUP were recorded in PPBCR4 (17.52 ha cm and 437.65 kg/ha cm) followed by MPCR2 (47.19 ha cm and 188.58 kg/ha cm, MPCR3 (113.03 ha-cm and 77.16 kg/ha cm), NPCR5 (169.66 ha cm and 58.58 kg/ha cm) and SPCR1 (170.44 ha cm and 76.57 kg/ha cm). Nutrients used in terms of NPK were recorded significantly lower and ANUP was significantly higher in PPCR4 (76 kg/ha and 89.74 kg/ha) followed by MPCR2 (187.02 and 46.86 kg/ha), MPCR3 (208.75 and 41.75 kg/ha), NPCR5 (375.50 and 26.41 kg/ha) and SPCR1 (380.22 and 34.07 kg/ha) respectively.

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