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PRODUCTION POTENTIAL AND SUSTAINABILITY OF MAIZE (*Zea mays*)—WHEAT (*Triticum aestivum*) CROPPING SYSTEM AS INFLUENCED BY BALANCED FERTILIZATION

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ABSTRACT

A field experiment was carried out in 2 tehsils namely Salumber and Sarada of Udaipur district situated in Humid Southern Plain Zone of Rajasthan (IVb) on 36 farmers' fields from kharif 2007 to rabi 2009-10 to study the influence of balanced fertilization on production potential and sustainability of maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system. Application of 90 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha in maize and 120 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha in wheat significantly improved grain and stover/straw yields, maize-grain equivalent yield, net returns and benefit cost ratio of maize-wheat cropping system over rest of the treatments. This treatment also registered maximum sustainable yield index (0.99), production efficiency (45.6 kg/ha/day), energy use efficiency (8.16), energy output efficiency (1317.6 MJ/ha/day) and energy productivity (282.1 g/MJ). Response studies indicated that maximum response was noted with phosphorus in both maize (15.1 kg/kg P) and wheat (23.4 kg/kg P).

Key words : *Maize–wheat cropping system, balanced fertilization, productivity, nutrient response, energetics.*

A diagnostic survey of 180 farmers conducted during 2007 revealed that maize (*Zea mays* L.)–wheat (*Triticum aestivum* L.)] is the most dominant and popular double cropping system under irrigated conditions in Humid Southern Plain Zone of Rajasthan, followed by maize- wheat-moong and maize-mustard cropping systems. The contribution of this cropping system to total food grain production of the country is considerably large, being 8.4% of maize (21.6 million t) and 36.5% of wheat (93.9 million t) (1). Continuous cropping of maize-wheat system has led to stagnation or decline in the productivity of both crops due to their exhaustive nature. Among the various agro-techniques, fertilizer is the single most important input in modern agriculture to raise the crop productivity. To get maximum returns, fertilizers must be applied in a well balance ratio, leading to their efficient utilization. Though information on nutrient management in individual crops is abundantly available, but the system based information is lacking. Moreover, single nutrient approach has been replaced by multi-nutrient so as to boost up crop productivity and nutrient use efficiency. Besides, nutrient management in cropping system is more efficient and judicious than individual crop, as succeeding crops take care of the residual effect of nutrients. The present experiment was therefore, undertaken to study the response of maize–wheat cropping system to balanced fertilization in terms of production potential and sustainability.

MATERIALS AND METHODS

A field experiment was carried out in 2 tehsils namely Salumbar and Sarada of Udaipur district situated in Humid Southern Plain Zone of Rajasthan (IVb) on 36 farmers' fields from kharif 2007 to rabi 2009-10. The soils of the experimental sites were sandy clay loam, having pH 8.4, low to medium available nitrogen, medium available phosphorus and high available potassium status. The experiment consists of 5 treatments viz., control, N, NP, NK and NPK applied to maize and wheat in sequence. The experiment was evaluated in randomized block design considering every farmer (12) as replication. The net plot size was 100 m^2 for each treatment. Maize cultivar 'PEHM 2' was sown during first fortnight of June to first fortnight of July and wheat cultivar 'Raj 4037' was sown during third week of November to first week of December. The recommended dose of NPK considered for maize was 90:40:30 kg/ha while for wheat, it was 120:40:30 kg/ha. Half dose of the nitrogen and full doses of P and K were applied at the time of sowing to both the crops while remaining half N was applied at 1 month after sowing in maize and split into ¼ each at first and second irrigation in wheat. Nitrogen, phosphorus and potassium were applied through urea, single super phosphate and muriate of potash, respectively. Besides, both crops were raised with recommended package of practices. Both the crops were evaluated in terms of grain and stover/straw yields, net returns and benefit cost ratio. On system basis, wheat grain yield was converted into maize-grain equivalent yield taking into account the prices of grains of the respective years. Production efficiency was calculated by dividing the maize-grain equivalent yield with total duration of maize-wheat system. Sustainable yield index (SYI) was calculated as per (2). Response of maize and wheat to N, P and K was calculated by using the following formulae (3) :

$$\text{Response of N (kg/kg)} = \frac{Y_N - Y_{cont}}{N}$$

Where,

Y_N = Grain yield under N treated plot (kg/ha)

Y_{cont} = Grain yield under control (kg/ha)

N = Amount of nitrogen applied (kg/ha)

$$\text{Response of P (kg/kg)} = \frac{Y_{NPK} - Y_{NK} + Y_{NP} - Y_N}{2P}$$

Where,

Y_{NPK} = Grain yield under NPK treated plot (kg/ha)

Y_{NK} = Grain yield under NK treated plot (kg/ha)

Y_{NP} = Grain yield under NP treated plot (kg/ha)

P = Amount of phosphorus applied (kg/ha)

$$\text{Response of P (kg/kg)} = \frac{Y_{NPK} - Y_{NK} + Y_{NP} - Y_N}{2K}$$

Where,

K = Amount of potassium applied (kg/ha)

The nitrogen use efficiency (kg grain/kg N applied) was calculated by the following formula (4) :

$$\text{NUE (kg grain/kg N applied)} = \frac{\text{Grain yield in N fertilized plots (kg/ha)} - \text{Grain yield in control plot (kg/ha)}}{\text{Quantity of N fertilizer applied in N fertilized plot (kg/ha)}}$$

Energy input and output was calculated using energy equivalents as suggested by (5). The energy use efficiency, energy output efficiency and energy productivity were calculated by using the following formulae :

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Energy output efficiency (MJ/ha/day)} = \frac{\text{Output energy (MJ/ha)}}{\text{Total duration of system (days)}}$$

$$\text{Energy productivity (g/MJ)} = \frac{\text{Grain yield (g/ha)}}{\text{Input energy (MJ/ha)}}$$

RESULTS AND DISCUSSION

Productivity

Maximum grain yield (3,160 and 5,188 kg/ha) and stover/straw yield (4,856 and 7,961 kg/ha) of maize and wheat were recorded with the application of NPK at recommended rates in both the crops and it was significantly superior over rest of the treatments, respectively (Table-1). The per cent increase in grain yield of maize due to application of NPK was 218.2, 45.5, 13.0 and 24.4 over control, N, NP and NK, respectively on mean basis. The respective increase in grain yield of wheat was 143.2, 39.8, 12.6 and 23.2%. Similarly, increase in stover/straw was 193.1, 41.5, 10.0 and 22.0% in maize and 137.1, 39.4, 12.5 and 22.2% in wheat, respectively. This was perhaps due to abundant supply of plant nutrients, which increased the protoplasmic constituents and accelerated the process of cell division and elongation which ultimately reflected in increased grain and stover/straw yields. Application of N over control, NP over N, NK over N and NPK over NP and NK also had advantage in significantly improving grain and stover/straw yields of both maize and wheat during all the years as well in mean data. Among the two nutrient combinations (NP and NK), NP application was found significantly superior to NK. The results are in agreement with the findings of (6).

Production efficiency and system productivity

Maximum production efficiency (45.6 kg/ha/day) and system productivity expressed in terms of maize-grain

Table-1 : Effect of NPK fertilization on grain and stover/straw yields of maize and wheat.

Treatment	Grain yield (kg/ha)								Stover/straw yield (kg/ha)							
	Maize				Wheat				Maize				Wheat			
	2007	2008	2009	Mean	2007-08	2008-09	2009-10	Mean	2007	2008	2009	Mean	2007-08	2008-09	2009-10	Mean
Control	1054	1008	917	993	2471	1951	1977	2133	1792	1642	1538	1657	3833	3264	2976	3358
N	2292	2138	2083	2171	3779	3603	3748	3710	3692	3388	3217	3432	5667	5912	5558	5712
NP	2975	2746	2671	2797	4992	4351	4481	4608	4696	4321	4225	4414	7408	7084	6736	7076
NK	2792	2517	2433	2581	4463	3955	4214	4211	4208	3958	3771	3979	6733	6474	6333	6513
NPK	3383	3133	2963	3160	5683	4852	5029	5188	5067	4871	4629	4856	8542	7663	7679	7961
CD (P = 0.05)	86	105	54	48	149	140	116	77	153	182	119	87	290	325	194	155

Table-2 : Effect of NPK fertilization on maize-grain equivalent yield, economics, production efficiency and nitrogen use efficiency of maize-wheat cropping system (Mean data of 3 years)

Treat-ment	Maize grain-equivalent yield (kg/ha)	Net returns (₹/ha)	Benefit cost ratio	Sustai-nable yield index	Production efficiency (MGEY kg/ha/day)	Nitrogen use efficiency (kg maize grain/kg applied N)	Nitrogen use efficiency (kg wheat grain/kg N applied)
Control	4084	20537	1.92	0.37	17.4	—	—
N	7590	54009	3.11	0.67	32.3	13.1	13.1
NP	9503	71832	3.63	0.88	40.4	20.0	20.6
NK	8717	64998	3.49	0.79	37.1	17.6	17.3
NPK	10705	83550	4.00	0.99	45.6	24.1	25.5
CD (P = 0.05)	113	1162	0.05				

equivalent yield (10,705 kg/ha) were obtained with the application of 90 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha in maize and 120 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha in wheat on mean basis (Table 2). The treatment having NPK was significantly superior to rest of the treatments. The lowest values of production efficiency (17.4 kg/ha/day) and system productivity (4,084 kg/ha) were recorded under the control due to lower yield of both the crops grown in sequence.

Sustainability

Balanced fertilization of NPK at recommended rates in both maize and wheat exhibited maximum yield stability of the system (0.99) where as the minimum sustainable yield index (0.37) was noted under the control. The omission of either of any nutrient (P, K or PK) caused reduction in sustainability of the system.

Response of nutrients and nitrogen use efficiency

The response (kg grain increase/kg nutrient applied) of maize to nitrogen was at par with that of wheat. On the other hand, response to phosphorus and potassium was higher in wheat compared to maize (Table-3). Amongst the nutrients, maximum response was noted with the application of phosphorus both in maize and wheat due to use of lesser quantity of P compared to N and more yield improvement per kg of nutrient applied. (7) also recorded similar finding. Imbalanced fertilization affected the nitrogen use efficiency (kg grain increase/kg applied nitrogen) of maize-wheat cropping system (Table-2). Nitrogen use efficiency was higher in NPK fertilized plots while lowest in case of only N fertilized plots for maize and wheat. Application of recommended

Table-3 : Response (kg grain increase/kg nutrient) of maize-wheat cropping system to various nutrients (Mean data of 3 years)

Nutrient	Maize	Wheat
N	13.1	13.1
P	15.1	23.4
K	12.9	18.0

Table-4: Effect of NPK fertilizer on energy use efficiency of maize-wheat cropping system (Mean data of 3 years).

Treatment	Input energy (x 10^3 MJ/ha)	Output energy (x 10^3 MJ/ha)	Energy use efficiency (output input energy)	Energy output efficiency (x 10^2 MJ/ha/day)	Energy productivity (x 10^2 g/MJ)
Control	23.86	117.75	4.94	5.01	1.71
N	36.66	219.63	5.99	9.35	2.07
NP	37.55	276.76	7.37	11.78	2.53
NK	37.07	252.88	6.82	10.76	2.35
NPK	37.95	309.64	8.16	13.18	2.82

doses of phosphorus and potassium with nitrogen in both the crops improved nitrogen use efficiency and it was found that phosphorus is more important than potassium to improve nitrogen use efficiency. Improvement in nitrogen use efficiency due to P and K application was also reported by (8).

Economic analysis

Application of 90 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha in maize and 120 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha in wheat resulted in the highest net returns (83,550/ha) and benefit cost ratio (4.00:1) in maize-wheat cropping system which was significantly superior to rest of the treatments (Table-2). This treatment recorded an additional net returns of ₹ 63013, 29541, 11718 and 18552/ha over, control, N, NP and NK, respectively.

Energetics

Compared to imbalanced fertilization and control, balanced fertilization in both maize and wheat crops recorded the highest input energy (37,954 MJ/ha) due to more inputs used under balanced fertilization (Table-4). Energy use efficiency (8.16), energy output efficiency (1,317.6 MJ/ha/day) and energy productivity (282.1 g/MJ) were also highest under NPK fertilized plots compared to rest of the treatments due to more yields. The lowest values of energy use efficiency (4.94), energy output efficiency (501.1 MJ/ha/day) and energy productivity (171.2 g/MJ) were recorded under unfertilized control in maize-wheat cropping system.

On the basis of three years' experimentation, it can be concluded that application of 90 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha in maize and 120 kg N, 40 kg P_2O_5 and 30 kg K_2O/ha in wheat could be recommended for improving the production potential and sustainability of maize-wheat cropping system.

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