Research Article

Fertilizer Management Strategies under Rainfed Conditions in Lentil Based Cropping Systems

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Abstract | To optimize fertilizer management strategies for rainfed cultivation under lentil (*lens culinaris*) based cropping systems field trials were conducted at University Research Farm, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi during 2007-2009. Lentil was planted in winter and during summer sorghum (*sorghum bicolor*) and mung bean (*vigna radiata*) followed lentil. Five different fertilizer treatments i.e. farmyard manure (FYM) 30 tons ha^{-1}, NPK 35-40-20 kg ha^{-1}, poultry manure 20 tons ha^{-1}, compost (press mud) 12.5 tons ha^{-1} and inoculation by phosphorus mobilizing microorganisms 2.5 packets ha^{-1}, in addition to control were evaluated under lentil-sorghum and lentil-mungbean cropping patterns. Fertilizer treatments were only applied to lentil while their residual effect was studied on sorghum and mungbean. The results revealed that net benefits and marginal rate of return from NPK were the highest mainly due to high lentil yield and poultry manure was next to it. The residual analysis confirmed the findings. Similarly sorghum gave higher returns than mung bean when grown after lentil. The studies showed that partial budget analysis was a reliable technique for farmers to optimize fertilizer recommendations and harvest maximum returns from their investment in agricultural business.

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Introduction

Pakistan is primarily an agricultural country with arid to semiarid climate. Rainfed areas occupy around 20% of the cropped area (Anonymous, 2012). Crop production in the region largely depends on rainfall with limited application of fertilizers. Fertilizers alleviate crops from stress but high cost limits their use (Wortmann and Ssali, 2001). Agricultural scientists generally recommend fertilizer based on technical suitability without giving due consideration to economic feasibility which is the main concern of farming communities (Anonymous, 2014). This results in poor adoption of the recommendations. Moreover, pulse production is about two time low in the region in spite of the favorable climate of the rainfed region (Mansoor, 2012). The economic perspective of the investment on fertilizers can help farming communities decide what type of nutrient source they might use to have maximum returns from their investment. Therefore, the present study focused on fertilizer management strategies in lentil based cropping system. Lentil is grown as a winter crop in rainfed tracts of Pakistan (Shah et al., 2009). In summer sorghum, millets and mungbean are commonly grown in areas receiving low to moderate rainfall in the Pothowar region. Due to high cost of chemical fertilizers, their use at farmers' field is low. Organic fertilizers, on the other hand are low cost and environment friendly. The fertilizer requirements for crop rotations including cereals and

legumes may be quite different and lentil-sorghum required more fertilizer.

Moreover, the input recommendations are normally static and are not dynamic to price changes (Shah et al., 2011). Therefore the current study was executed with specific objectives to optimize organic and inorganic fertilizer input recommendations for lentil-mungbean and lentil-sorghum cropping systems on economic parameters based on real type data from field experiments instead of statistical estimates.

Materials and Methods

The experiment was conducted at University Research Farm, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, under rain fed conditions. The experimental soil was sandy-clay loam in nature and having pH 8.07, organic matter 0.33%, total nitrogen 0.025%, available phosphorus 3.05 mg kg^{-1} and extractable potassium 90 mg kg^{-1}. The experiment was designed to study the effect of organic and inorganic fertilizers tested under lentil-sorghum and lentil-mungbean cropping systems on productivity for two years starting from 17 November 2007 and ending 25 November 2009. Summer crops were sown 23 July 2007 and 28 July 2008. The influence of five different organic and inorganic fertilizers was evaluated in two different cropping systems, using randomized complete block design with split plot arrangement on the basis of crop productivity and economic returns. Subplot size was kept at 3 × 5 m. Organic fertilizers, i.e., FYM, PM and compost, were applied through broadcast, fifteen days before sowing and incorporated in the soil. Among inorganic fertilizer full recommended dose of phosphorus (in the form of DAP), potassium (in the form of SOP) and half dose of nitrogen (in the form of Urea) were manually broadcasted at the time of sowing and half N after 45 days of sowing. Each plot was examined during crop growing season and manual hoeing was done to eradicate the weeds. Lentil (masoor 2002) and mungbean (Mung 97) were sown using seed rate of 25 kg ha^{-1} each in 30 cm apart rows. Sorghum (Chakwal 2002) was planted at the rate of 40 kg ha^{-1} placing the seeds in 45 cm apart rows by hand drill.

Different cropping systems and fertilizer levels were as under:

Cropping systems

CS_1= Lentil-Mungbean

CS_2= Lentil-Sorghum

Fertilizer treatments

T_0= Control

T_1 = Farmyard Manure (FYM) 30 tons ha^{-1}.

T_2 = NPK 35-40-20 kg ha^{-1}

T_3 = Poultry manure 20 tons ha^{-1}.

T_4 = Compost (Press mud) 12.5 tons ha^{-1}.

T_5 = Inoculation by phosphorus mobilizing microorganisms 2.5 packets ha^{-1}.

Following analytical techniques were used to optimize the input on economic parameters using procedure adopted by CIMMYT (1988) and Shah et al. (2012):

Partial budget analysis

Gross field benefits were calculated as (GB_f):

$$GB_f = P_f x\, Y_{adj}$$ (CIMMYT, 1998)

Where,

GB_f = gross field benefits

P_f = field price

Y_{adj} = adjusted yield

Net Benefits were calculated as:

$$NB = GB_f - TCV$$ (CIMMYT, 1998)

Where,

NB = net benefits

TCV = total costs that vary

Dominance analysis

Dominance analysis were carried out by listing the treatments with higher cost that vary (CIMMYT, 1998).

Marginal rate of return

Farmer can change one practice to another by MRR which tells that what he gained from investment, it was calculated by using formula (CIMMYT, 1998):

$$MRR = (\delta NB / \delta TCV) \times 100$$

Where,

δ NB = change in net benefits

δ TCV = change in total costs that vary

Analysis using residual

The conclusion of a marginal analysis can be checked by the concept of residuals. It is the comparison between the residuals, rather than their absolute value, that was of interest. The treatments with highest value of residual were recommended in this study (CIMMYT, 1998):

$$Residual = (NB - Returns\ Required)$$

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NPK ratio in organic matters

NPK ratio in organic matter is given in Table 1.

Results and Discussion

Partial budget analysis of lentil followed by sorghum and mung bean cropping system are presented in Table 2 and 3. The Cost that Vary for the treatment T_1 was highest followed by T_4, T_3, T_2 and T_5, respectively among the experimental treatments. However, the net benefits for T_2 were highest mainly due to high lentil yield. Lentil-Sorghum cropping system without fertility treatment gave net benefits Rs. 31046 ha^{-1}, while, lentil treated with FYM, NPK, PM, compost and PSB gave per hectare net benefits of Rs. 99931, 128970, 121801, 74878 and 36159, respectively. Use of recommended dose of NPK for lentil and its residual effect on production of sorghum in summer gave maximum net benefits, so it was recommended for lentil-sorghum cropping system. Partial budget for lentil-mungbean cropping system without treatments gave net benefits Rs. 38248 ha^{-1} while, in case of recommended fertility treatments for lentil and their residual effect on summer grown mungbean, FYM,

Table 1: *NPK ratio in organic matter*

Organic Matter	N (%)	P (%)	K (%)
Farm yard manure	0.83	0.63	0.54
Poultry Manure	0.77	0.70	0.64
Compost	0.34	0.53	0.54
Inoculum	0.18	0.15	0.41

Table 2: *Partial budget of lentil-sorghum cropping system*

Economic analysis	Treatments					
	T_0 Control	T_1 FYM (30 tons ha^{-1})	T_2 NPK (35+40+20 kg ha^{-1})	T_3 PM (20 tons ha^{-1})	T_4 Compost (12.5 tons ha^{-1})	T_5 PSB (2.5 *Packet. ha^{-1})
Total Costs that Vary (Rs. /ha)	0	10950	7767	9350	9675	650
Gross Benefits from Lentil (Rs./ha)	15535	72280	79105	78130	50050	19500
Net benefits from Lentil (Rs./ha)	15535	61330	71338	68780	40375	18850
NB from sorghum	15511	38601	57632	53021	34503	17309
Total NB With Lentil Followed By Sorghum (Rs./ha)	31046	99931	128970	121801	74878	36159

*(*Rs. 100 = 1$ in 2008) NPK was Rs. 76.49/kg (to convert on hectare bases multiply with 95); One packet is =One Kg*

Table 3: *Partial budget for lentil-mungbean cropping system*

Economic analysis	Treatments					
	T_0 Control	T_1 FYM (30 tons ha^{-1})	T_2 NPK (35+40+20 kg ha^{-1})	T_3 PM (20 tons ha^{-1})	T_4 Compost (12.5 tons ha^{-1})	T_5 PSB (2.5 *Packet. ha^{-1})
Total Costs that Vary (Rs./ha)	0	10950	7767	9350	9675	650
Gross Benefits from Lentil (Rs./ha)	15535	72280	79105	78130	50050	19500
NB from Lentil (Rs./ha)	15535	61330	71338	68780	40375	18850
NB from mungbean (Rs./ha)	22713	45075	50381	47958	34579	25266
Total NB With Lentil Followed By mungbean (Rs./ha)	38248	106405	121719	116738	74954	44116

Lentil seed price = Rs. 65/kg; One packet is= One Kg

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NPK, PM, compost, and PSB gave per hectare net benefits of Rs. 106405, 121719, 116738, 74954 and 44116, respectively. Among the treatments maximum net benefit was provided by NPK (T_2) that was recommended for use in lentil-mungbean cropping system to obtain maximum net benefit.

Dominance Analysis was conducted as it is a prerequisite for further economic analysis to identify the dominated treatments for which the net benefit decreased while cost that varies increased (Table 4). Compost, farmyard manure (FYM) and NPK dominated as their cost was high as compared to the previous one with higher net benefits. Hence these treatments would be excluded from the further analysis.

Table 4: *Dominance Analysis for lentil-sorghum and lentil-mungbean cropping system*

Treatment	*TCV	NB for lentil-sorghum	NB for lentil-mungbean	
T_0	0	31046	38248	
T_5	650	36159	44116	
T_2	7767	128970	121719	
T_3	9350	121801	116738	D
T_4	9675	74878	74954	D
T_1	10950	99931	106405	D

**Total Costs that Vary*

Table 5: *Marginal Analysis for lentil sorghum-cropping system*

Treatment	TVC	NB	Change in TVC	Change in NB	MRR (%)
T_0	0	31046			
T_5	650	36159	650	5113	787
T_2	7767	128970	7117	92811	1304

Table 6: *Marginal analysis for lentil-mungbean cropping system*

Treatment	TCV	NB	Change in TCV	Change in NB	MRR (%)
T_0	0	38248			
T_5	650	44116	650	5868	903
T_2	7767	121719	7117	77603	1090

The returns on the investment for different experimental treatments were evaluated through marginal analysis as measured through Marginal Rate of Return (MRR). The results for lentil-sorghum system as depicted in Table 5 indicated that the NPK gave highest rate of return as the MRR is equal to 1304 percent which showed that one rupee invested in NPK treatment would give an additional 13.04 rupees to farmer when he moved from PSB to NPK. The returns by moving from control to PSB are 787% and when we moved to next NPK the returns were 1090%. Hence based on marginal analysis NPK could be recommended. The results for Lentil-Mungbean system as depicted in Table 6 indicated that the NPK gave highest rate of return as the MRR is equal to 1090 percent which showed that one rupee invested in NPK treatment would give an additional 10.90 rupees to farmer when he moved from PSB to NPK. The returns by moving from control to PSB are 903% and when we moved to next NPK the returns are 1090%. Hence based on marginal analysis NPK could be recommended.

The analysis using residual was conducted to confirm the results of marginal analysis. Through residual analysis (Table 7) different recommendation was proved as the residual value for T_2 was higher than T5 and as per procedures (CIMMYT, 1998; Shah et al., 2011) the treatment with highest value T_2 was recommended as it gave highest net income to the farmer. NPK gave maximum residual return Rs. 121203 ha^{-1} in case of lentil-sorghum cropping system among the treatments because of low total cost that vary and high net benefits in that way NPK was recommended. NPK gave maximum residual return (Table 8) Rs. 113952 ha^{-1} in case of lentil-mungbean cropping system among the treatments because of low total cost that vary and high net benefits in that way NPK was recommended.

Table 9 showed that in rainfed region lentil-sorghum cropping system was better than lentil-mungbean for higher economic returns due to high demand of fodder in Pothowar area, where sorghum yield more quantity of fodder in terms of stalks, thus gave more economic returns than mungbean straw, being low in tunnage. Impact on soil fertility required long period experimentation for recommendation at farmers' level.

Poor soil fertility has emerged as one of the greatest biophysical constraint to increasing agricultural productivity hence threatening food security (Mugwe et al., 2009). The results of this study revealed that net benefits and marginal rate of return from NPK were the highest mainly due to high lentil yield and poultry manure was next to it. Although chemical fertilizers (NPK) gave better economic returns and for instant

Table 7: *Residual Analysis of lentil–sorghum cropping system*

Treatment	TVC	NB	Returns Required 100%×(TVC)	Residual=(NB-Returns Required) (Rs.)
T_0	0	31046	0	31046
T_5	650	36159	650	35509
T_2	7767	128970	7767	121203

Table 8: *Residual analysis for lentil–mungbean cropping system*

Treatment	TCV	NB	*Returns Required100% x(TCV)	Residual = (NB-Returns Required)
T_0	0	38248	0	38248
T_5	650	44116	650	43466
T_2	7767	121719	7767	113952

**The minimum returns required to farmers to adopt the new techniques*

Table 9: *Comparison of lentil based sorghum and mung-bean cropping system for the recommended treatments*

Treatment	Variables	Lentil-Sorghum	Lentil–Mungbean
T_2	NB	128970	121719
	MRR (%)	1304	1090
	Residual Value	121203	113952

benefit are good to use, organic fertilizers including farmyard manure and poultry manure and bio-fertilizer may be used for crop production as a substitute of chemical fertilizers (Khan et al., 2005; Ayoola et al. 2007). In Pakistan, poultry manure is gaining popularity due to expanded poultry industry in the country. The available poultry manure in the country can be used to replace up to 101,000 tons of nitrogen, 58,000 tons of phosphorus and 26, 000 tons of potassium in the form of chemical fertilizer (Bari, 2003), which on one hand, can help to cope with the environmental issues and on the other hand provide long term benefits to cultivated soils.

In case of lentil-sorghum cropping pattern maximum return per ha was obtained from NPK treated plots which gave Rs. 10.90 on Rs.1 investment while lentil-mungbean cropping sequence gave the maximum response to same treatment with lesser marginal rate of return. The reason in difference for the net benefits and marginal rate of return for cropping sequences was due to the market value of the crop or its by-products. Sorghum crop economically dominated over mung bean due to high demand as fodder and seed. The high biomass of sorghum economically made it dominant over mungbean having less price. Our findings are in the line with the findings of Arif and Malik (2009), Amanullah and Almas (2009).

Conclusions and Recommendations

The study highlighted important discrepancies between technical and economic optimum as the yield and return of lentil was high for T_2 (NPK), while for yield next best treatment was T_3 (Poultry Manure). Same findings were confirmed by marginal analysis and analysis using residual. The higher returns were due to low cost of recommended treatment along with higher residual impact. This also highlighted the importance of residual effect related to the cropping pattern. Therefore, it is recommended that the input recommendation should be developed based on market factors i.e., costs and benefits and system aspects i.e., cropping pattern.

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