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MUNGBEAN (*VIGNA RADIATA*) IN WHEAT BASED CROPPING SYSTEM: AN OPTION FOR RESOURCE CONSERVATION UNDER RAINFED ECOSYSTEM

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Abstract

Pakistan has 17 agro-ecological zones and in 11 of these rainfed agriculture prevails. The present paper gives an account of the experimental evidence demonstrating the potential importance of mungbean in the rainfed cropping systems with the goal to develop a sustainable agriculture at a higher level of productivity and profitability. Agro-economic studies of mungbean-wheat and fallow-wheat cropping systems revealed that water requirement for mungbean growth cycle varied depending upon seasons, potential evapotranspiration (ETo) and crop coefficients. Under agro-ecosystem of Islamabad, rainfall is surplus than water requirements of mungbean. The study also showed that the response of wheat growth, development and yield differ significantly when followed after mungbean crop as compared to fallow. Net monetary benefits of Rs.5820 per hectare could be obtained by sowing Mungbean in wheat based cropping system.

Introduction

The cropped area of Pakistan consists of 20.9 mha, of which 4.8mha (24.4%) is rainfed and concentrated in Potohar uplands, northern mountains and northeastern plains (Anon., 1988). The Islamabad zone centers on the Potohar plateau, comprises districts of Islamabad, Rawalpindi, Attock and Chakwal. The zone entirely depends on rainfall and are characterized by a diverse and complex agriculture, reflecting the interaction of land type, soil type, rainfall variability and socio-economic factors in farmers management (Supple *et al.*, 1985).

The barani soils are subjected to sheet and gully erosion and it is intensified with the commencement of monsoon rains due to the fallow system where the absence of vegetation makes the soil susceptible to erosion. This results in loss of organic matter, plant nutrients and also reduce rate of water infiltration and soil water storage capacity. Ahmad *et al*. (1990) reported annual soil loss of 17-41 t ha^{-1} due to fallow compared to 9-26 t ha^{-1} when the land was under a crop. They also found that in this region crop cover reduced the annual surface run off by 10-18% and reduced soil loss by 50%. It is important to mention that cropping intensity in these areas is low and increasing it will improve resource productivity. The potential for reducing fallow land with leguminous crops is prevailing considerably high (Supple *et al*., 1985; Byerlee *et al*., 1992). The introduction of Mungbean-Wheat system instead of Fallow-Wheat system appears feasible in medium and high rainfall areas as a mean of economically maintaining nitrogen balance in the agro-ecosystems and will provide opportunity for more grain production and protein content. Mungbean maintain soil fertility and sustain system productivity. Farmers in medium rainfall areas who replaced fallow with mungbean were able to raise their net system income (Majid *et al.,* 1990). In high rainfall areas the Mungbean-Wheat system gave promising performance. It was suggested that Mungbean based wheat systems in high rainfall areas will help farmers to sustain system productivity through moisture conservation, stable economic benefits, improvement in soil nutrition and organic matter over time (Aslam, 1995). The present study demonstrates the potential of Mungbean in the rainfed ecosystem with the objectives of evaluating the environmental, agronomic and economic feasibility in rainfed agro-ecosystem. This will provide information regarding inclusion of mungbean crop in the existing wheat based cropping systems, and will help for effective use of natural resources.

Rainfed agro-ecosystem

Climate: The districts of Islamabad zone have three distinct rainfall zones i.e., high rainfall (>750 mm of annual rainfall), medium rainfall (500 to 750 mm), and low rainfall (<500 mm). In these rainfed areas almost 60% rain is received during summer (June-September) and 40% during rabi (October-May), whereas copping intensity is considerably low during summer as a lot of land is left fallow. Analysis of long-term (1961-2000) climatological data of Pakistan Meteorological Department on the basis of rabi and kharif seasons (Fig. 1 and 2) revealed that from rainfall distribution and frequency it may be predicted that there are possibilities to increase cropping intensity of the area by reducing the fallow land.

Soil: Soils of the area are generally medium textured to clay-loam and are low in natural fertility. Nitrogen, organic matter and phosphorus are deficient, however, potash level is adequate. The soils are having pH of 7.5 to 8.5 (Ahmad *et al*., 1988).

Feasibility of mungbean-wheat cropping system

Water requirements of mungbean: A crop can be well suited to an ecosystem if its water needs are met during its life cycle. The procedures to estimate water requirements under rainfed environments were adopted from FAO (Anon., 1986) and Doorenbos & Pruitt (1977). Potential evapotranspiration (ETo) was calculated on the basis of Penman (1948) for a given environment using local weather parameters. The crop coefficients (Kc) for the same ecology were drawn from the Mungbean growth behavior by dividing its growth period into four growth stages named as initial stage, crop development stage, mid season and late season stages. Precise water requirements were calculated on the basis of 10-day period (Dekad), as suggested by WMO (Anon., 1966) and Doorenbos & Pruitt (1977), by multiplying the ETo for a given dekad by the Kc for the same dekad. The available water was expressed by subtracting the water requirements from amount of actual rainfall during that dekad. It is expressed as surplus when subtracted values were positive; otherwise it was a deficit (Table 1 & 2). Water requirements and crop coefficients were high from second dekad of August to second dekad of September, because this was the period when crop completed vegetative phase and flowering was also completed. Total water requirements of mungbean for whole growing period were 325.9 and 360.3 mm during 1992 and 1993 respectively. More water requirements during 1993 were due to high temperatures and because of greater values of potential evapo-transpiration. From the water requirements of Mungbean (Table 1 & 2) and the data of rainfall (Fig. 1) it is verdict that overall the rainfall received during kharif is always surplus than the water requirements of Mungbean. It may be concluded from the scenario that the precious natural resource of water from rainfall can be efficiently used to raise a crop like mungbean which require significantly less amount of water than available through rainfall.

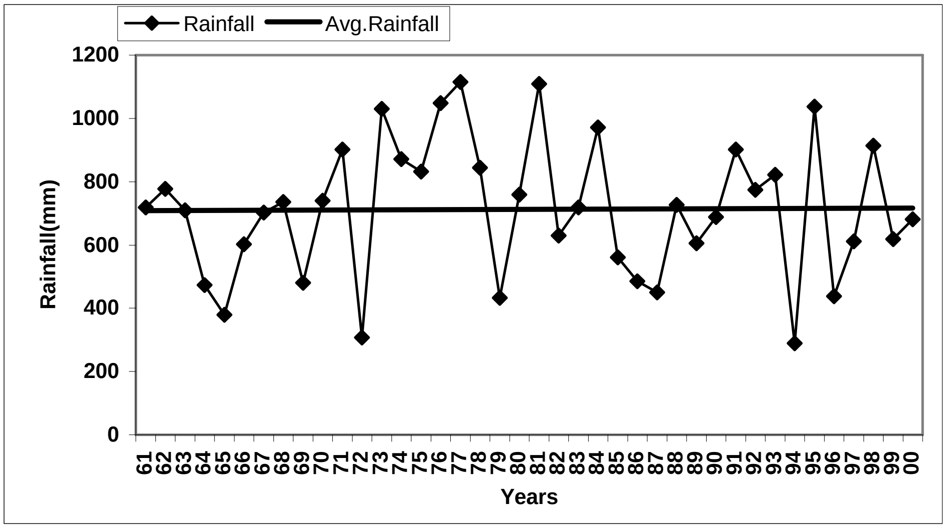

Fig. 1. Rainfall in Islamabad zone during kharif season (1961-2000).

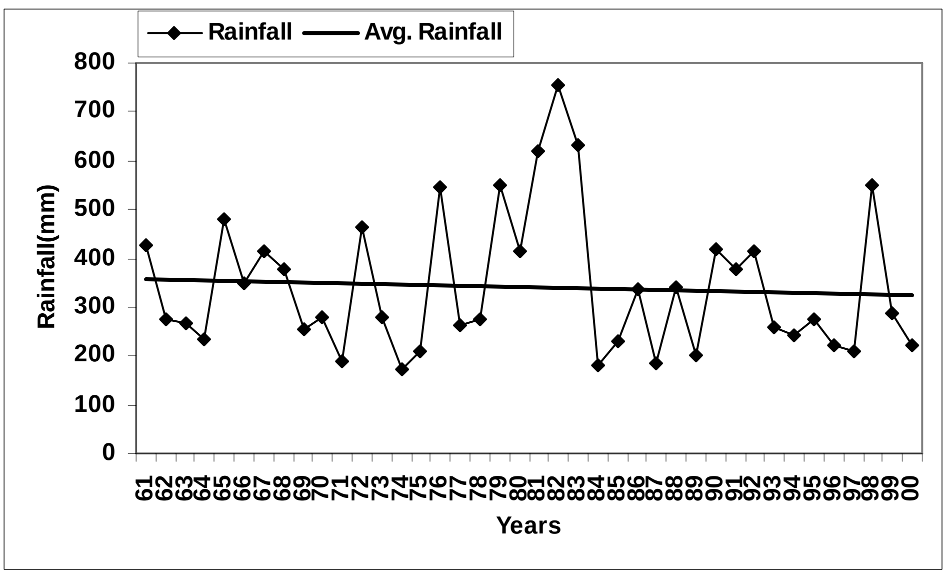

Fig. 2. Rainfall in Islamabad zone during rabi season (1961-2000).

Agro-economic performance of mungbean: Yield and yield components (Table 3) of Mungbean revealed that there were significant differences in plant height, pods per plant and pod length during both seasons. During kharif, 1992 plants attained a height of 86.4 cm, while, during kharif, 1993 plant height was 67.7 cm. There were 32.7 pods per plant and pod length was 7.2 cm during kharif, 1992; whereas 42.5 pods per plant with pod length of 6.1 cm were recorded during kharif, 1993. It is important to note that there are biological variations in the performance of mungbean crop such as with the increase in plant height;

number of pods per plant was reduced, whereas pod length increased. Similarly, seed yield and other components viz., 1000-seed weight, total biological yield and harvest index showed non-significant differences. It showed the mungbean's ecological behavior compensates the overall economic yield of the plant. On average seed yield of 992.4 kg ha^{-1} was attained in a year by sowing Mungbean in rainfed ecosystem during kharif. Zahid, *et al*., (1991), reported seed yield of 678 kg ha^{-1} when they planted mungbean in mungbean-wheat cropping system at Fatehjang, which is situated in medium rainfall areas of "Pothwar". Mungbean also provided 27% of protein contents, which is not only a good and cheap source but also offers the most practical means of eradicating protein malnutrition in the diet of the populations of the area.

Table 1. Water requirements of mungbean (Kharif 1992).

Month	Decade	Rainfall (mm)	Potential Evapotranspiration (mm)	Crop Coefficient (Kc)	Water Requirements (mm)	Water Available (S/D)*
July	3	90.8	69.3	0.40	27.7	+ 63.1
	1	128.5	58.0	0.55	31.9	+ 96.6
Aug.	2	31.9	61.1	0.88	53.8	- 21.9
	3	22.4	62.2	1.05	65.3	- 42.9
	1	345.3	47.9	1.05	50.3	+ 295.0
Sep.	2	13.1	47.5	1.05	49.9	- 36.7
	3	0.0	47.4	0.75	35.5	- 35.6
Oct.	1	6.6	38.4	0.30	11.5	- 4.9
Total		**638.6**	**431.8**		**325.9**	**+ 312.7**

*Surplus or deficit.

Table 2. Water requirements of mungbean (Kharif 1993).

Month	Decade	Rainfall (mm)	Potential Evapotranspiration (mm)	Crop Coefficient (Kc)	Water Requirements (mm)	Water Available (S/D)*
July	3	48.5	75.0	0.40	30.0	+ 18.5
	1	152.4	62.4	0.60	37.4	+ 114.9
Aug.	2	33.0	68.9	0.90	62.0	- 29.0
	3	39.5	73.3	1.05	76.9	- 37.5
	1	159.0	47.8	1.05	50.2	+ 108.8
Sep.	2	60.7	50.6	1.05	53.1	+ 7.6
	3	9.1	45.5	0.83	37.8	- 28.7
Oct.	1	0.0	42.6	0.30	12.8	- 12.8
Total		**502.2**	**466.1**		**360.2**	**+ 141.9**

*Surplus or deficit.

Table 3. Yield and yield components of mungbean.

Parameters	Kharif 1992	Kharif 1993	LSD (0.05)	Means
Plant height (cm)	86.4	67.7*	8.32	77.0
Pods per plant	32.7	42.5*	7.78	37.6
Pod length (cm)	7.2	6.1*	0.74	6.7
1000- seed weight (g)	35.6	32.5 NS	9.89	34.0
Biological yield (Kg Ha^{-1})	8276.5	9755.6 NS	2472.9	9016.0
Seed yield (Kg Ha^{-1})	1002.9	981.9 NS	248.3	992.4
Harvest index (%)	12.6	10.2 NS	5.6	11.4
Protein (%)	28.4	25.6*	1.4	27.0

*Significant at 0.05 probability

NS = Non significant

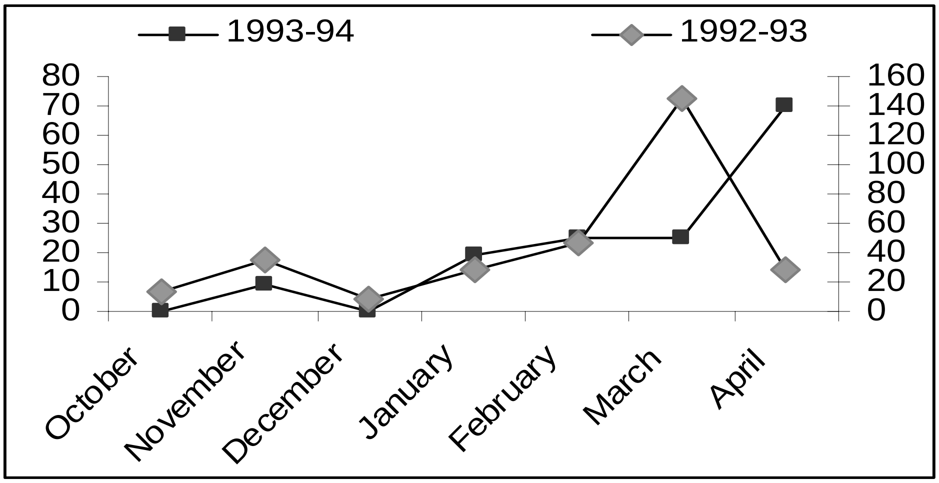

Fig. 3. Rainfall (mm) variations in Islamabad zone during wheat growing seasons (1992-1994).

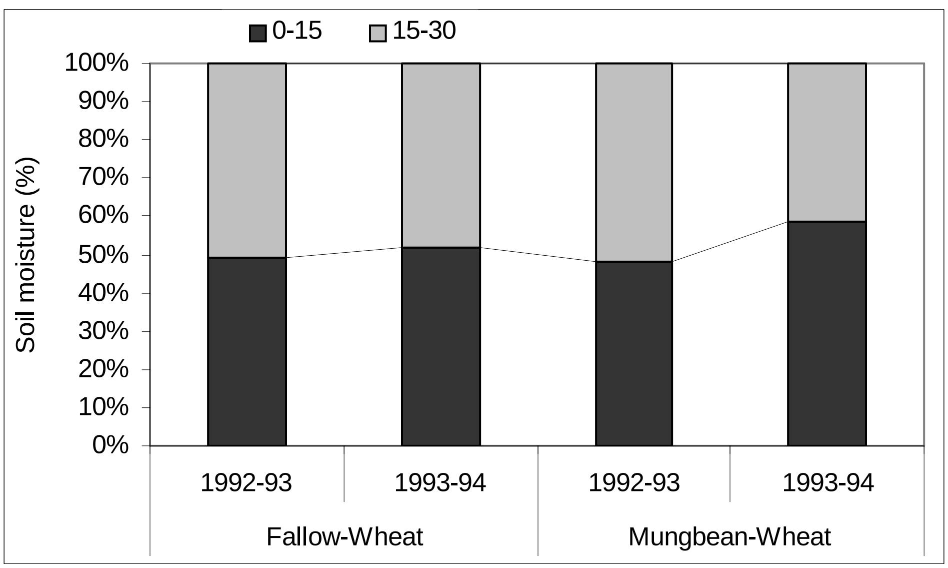

Fig. 4. Soil Moisture (%) content for Wheat establishment after fallow and Mungbean cropping systems.

Mungbean based cropping system and soil moisture: Soil, a strategic resource for agriculture, is a living biological system. Decline in soil productivity, environmental quality and progressive deterioration of natural resources have led to rummage around for new methods to sustain crop production by means of more efficient nutrient cycling and resource conservation. Legumes, such as mungbean, play a vital role in such systems by protecting the soil from erosion, by enriching it with organic matter and N through *Rhizobium* symbiosis and by conserving precious natural resources like water in the soil.

Soil moisture is an imperative element in rainfed ecosystem for obtaining satisfactory crop establishment. After Mungbean crop soil moisture increased in the rooting zone (Fig. 4), which led to rapid emergence of wheat crop and a satisfactory crop establishment, which is an important factor in the prevailing agro ecosystem because of the marginal moisture level.

Mungbean based cropping system and soil fertility: Nitrogen (NO_3^{-1}) and organic matter contents in the soil was gradually increasing with time (Fig. 5). Because of high nitrogen concentration of their tissues, Mungbean plants can increase soil nitrogen for the subsequent crop due to the fixation of free atmospheric nitrogen. Mungbean could therefore contribute to sustainability of food production by enriching the soil through biological nitrogen fixation and improving the soil's physical conditions, its quality and sustainability. Mungbean grown in rotation with wheat can grab hold of soil N that might otherwise be lost by denitrification or leaching due to heavy rainfall in kharif.

Wheat in mungbean and fallow based cropping systems: Stepping up food production per unit area is needed to keep pace with population growth. Residual soil moisture controls the germination and emergence through the process of imbibition. Wheat seedling stand established after Mungbean was higher as compared to that after fallow (Table 4).

Number of fertile tillers per unit area is an important yield component in wheat. Higher yields are often associated with higher number of fertile tillers per unit area. More fertile tillers were produced in mungbean-wheat cropping system (310.9) than fallow-wheat (292.5) system (Table 4). Higher number of fertile tillers after Mungbean may be due to moisture conserved and nitrogen fixed by Mungbean to help these foundations.

In rainfed areas wheat grain yield is a combined product of its yield components and much depend on seasonal available moisture. Intermittent availability of soil moisture (Fig.2) particularly during grain fill (Fig. 3) will affect the grain yield. Differences in yield are frequently associated with differences in grain size, which depends on the number of grains per ear and may have been limited to some extent by the supply of assimilates. Responses of wheat to management practices designed to extend the duration of grain fill and increase kernel weight partially depend on the climatic condition during grain fill periods. Grain yield was 3503.0 kg ha^{-1} in mungbean-wheat as compared to 3308.0 kg ha^{-1} in fallow-wheat cropping system in one year while it was 2026.0 kg ha^{-1} and 2312.5 kg ha^{-1} in the other year. The higher grain yield or yield at par in Mungbean-Wheat system is one of the important platitudes of this system over fallow from farmer's point of view.

Economics of mungbean-wheat and fallow-wheat cropping systems: Economics is the dominant factor influencing the adoption of cropping systems. The economic analysis of both the cropping systems was done using the methodology described in the Economic Programme of CIMMYT (Anon., 1988).). The purpose was to evaluate the differences in costs and benefits between these two cropping systems. The total gross benefit of both the cropping systems when compared, mungbean-wheat cropping system gave the higher gross return (Table 5) than the fallow-wheat system. Net benefits of Mungbean-wheat system were also higher than fallow-wheat system. So, economically Mungbean is found feasible in rainfed agro-ecosystem and will help to improve the socio-economic conditions of the farmers of this area with the increase in income and will ultimately improve their livelihood.

Table 4. Performance of wheat after Mungbean and fallow.

Cropping systems	Germination (m^2)			Fertile tillers (m^2)			Grain yield (kg ha^{-1})		
	1992-93	1993-94	Mean	1992-93	1993-94	Mean	1992-93	1993-94	Mean
Fallow-Wheat	178.8	172.3	175.6	338.5	246.5	292.5	3308.0	2312.5	2810.2
Mungbean-Wheat	185.0	170.3	177.6	388.8	233.0	310.9	3503.0	2026.0	2764.5

Table 5. Economics of mungbean-wheat and fallow-wheat cropping systems.

Cropping systems	Gross benefit (Rs. ha^{-1})	Costs that vary (Rs. ha^{-1})	Net benefits (Rs. ha^{-1})
Fallow-Wheat	11515.95	4355.12	7160.83
Mungbean-Wheat	19399.29	6418.59	12980.70

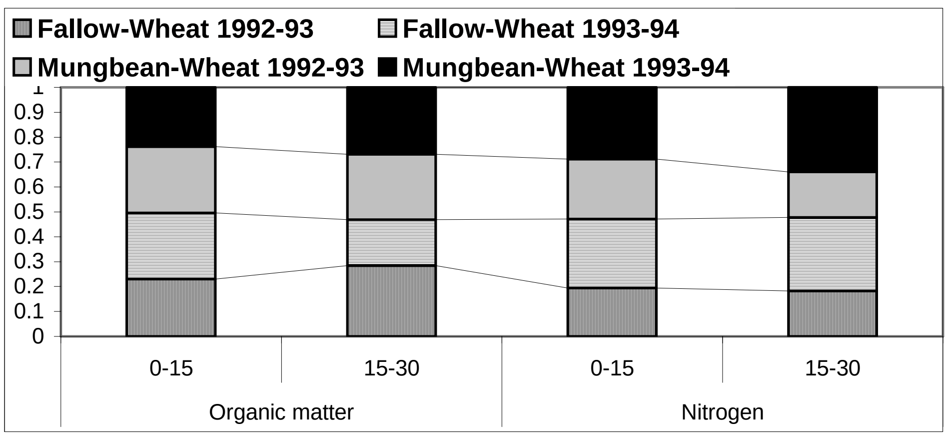

Fig. 5. Soil Nitrogen (NO_3^{-1}) status and Organic Matter (mg Kg^{-1}) after fallow and Mungbean cropping systems.

Conclusion

Mungbean fits very well in the rainfed agro ecosystem as it helps water conservation and nutrient recycling for the total system. Because Mungbean can obtain nitrogen from the atmosphere, hence the crop may be independent of nitrogen fertilizer reducing the cost of production and minimizing pollution. In addition, having Mungbean in rotation with wheat crop is a simple management technique, which can help to minimize weeds, pests and pathogen for the subsequent wheat crop. Mungbean will contribute towards soil fertility through nitrogen fixation; through deep root system that will utilize and recycle nutrients at depth; through residues that increase organic matter and improve soil structure; and through protection of the soil from erosion.

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