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EFFECTS OF VARIOUS CROPPING SYSTEMS AND DIFFERENT FERTILITY SOURCES ON SUBSEQUENT WHEAT CROP

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ABSTRACT

A biennial field trial was conducted on inceptisol of Pothwar, Pakistan to evaluate potential of five fertility treatments: no fertilizer; inoculation + Phosphorus and Potash (PK); Nitrogen, Phosphorus and Potash (NPK); poultry manure (PM) and half poultry manure + half PK + inoculation and to find out most promising combination maize-wheat; maize + black gram-wheat; maize + mungbean-wheat; black gram-wheat and mungbean-wheat under diverse fertility sources. Results of the study revealed an increase of 12 % and 11% in grain yield of wheat after black gram and mungbean, respectively compared to wheat grown after maize. Black gram-wheat sequence gave 19 % higher water use efficiency compared to maize-wheat system. The yield of wheat increased by 20 % in plots previously treated with poultry manure @ 15 t ha^{-1} over no fertilizer. Plots amended with poultry manure in summer season registered 13 % higher water use efficiency of wheat over no fertilizer. Hence, legume-cereal (black gram-wheat) cropping sequence with poultry manure proved to be more productive and sustainable than cereal-cereal (maize-wheat) rotation.

Key words: Wheat, legumes, grain yield, PGPR, cropping systems

INTRODUCTION

Wheat (*Triticum aestivum* L.) is categorized staple food of the people and principal food grain in Pakistan; it plays a pivotal role in development of agricultural policies. It contributes 3.1 percent to GDP and shares 14.4 percent in the value addition of agriculture. Wheat is the vital part of diet of population and reigns prime in food security of the country. Wheat was grown on an area of 8693 thousand hectares in 2012-13 that was 0.5 percent more over the area sown last year. There was 24.2 million tons during 2012-13 against the set target of 25.5 million tons in 2012-13. With the population growth rate at around 2.4%, the demand for wheat grain will increase many folds in the years to come. Consequently, there is a dire need to increase wheat production to meet food demand for increasing population in the country. The wheat average yield is very low in comparison to the developed countries. The factors responsible for this low yield are multifarious. The most important reasons are inadequate and irrational use of fertilizers and the d mining of native soil nutrients, low organic matter of soil and choice of improper cropping system.

With the population growth rate at around 2.4%, the demand for wheat grain will increase many folds in the years to come. Consequently, there is a dire need to increase wheat production to meet food demand for increasing population in the country. Cropping systems vary according to physical features of land, ecological amplitudes, availability of capital, manpower and diversified household needs.

Among different cropping systems, a well planned cropping rotation reduces disease pressure and insect pests, improves organic matter, ameliorates soil structure, levels, prevents explosion of weeds and augment the crop yield. Crop production, soil fertility and productivity could be achieved by incorporating legumes in two year cropping sequence (Kumbhar *et al*., 2007). To maintain the soil productivity and sustainability, legumes must be included in crop rotations. For getting maximum return, different crops should be included in crop rotation (Giller, 2001). Nutrient sources are made available to the plants by the action of soil micro-organisms, nitrogen self sufficiency through the biological nitrogen fixation (Hossain *et al*., 2004). Wheat yield was increased with soybean as a preceding crop as compared to sorghum- wheat sequence (Ghosh *et al*., 2004). Wheat yield increased significantly after mungbean crop (Asim *et al*., 2006). Phosphorus along with *Rhizobium* inoculation in legumes improved soil fertility for sustainable agriculture (Fatima *et al*., 2007).

Persistent use of mineral fertilizers though in reasonable ratio is not able to sustain crop productivity owing to soil fertility impairment (Zia *et al.*, 2000). Per hectare yield has not been improved proportionally in spite of increased utilization of the fertilizers; (Ali, 2000). Organic fertilizers including poultry manure, sheep manure farmyard manure, and bio-fertilizer may be an alternative of chemical fertilizers for crop production (Khan *et al*., 2005). Though organic fertilizers supply all the necessary elements needed for growth but not in balanced proportion (Afzal *et al*., 2005). Organic matter from organic fertilizers has a strong effect on water retaining capacity and improvement in soil structure (Sharif *et al*., 2004). Poultry manure adds organic matter to soil which improves nutrient retention, aeration, soil structure and water infiltration (Deksissa *et al*., 2008). Likewise, Phosphorus is more readily available to plants from poultry manure compared to rest of organic manure (Garg and Bahla, 2008).

Recent energy crisis, soaring outlay of crop husbandry, retreating soil fertility, and increased prices of mineral fertilizers calls for integrated approach for crop production. For sustainable crop production, a system integrating diverse management practices for retaining soil fertility is mandatory and this would be the inclusion of legumes in existing cropping system and the judicious use of various fertility sources. The potential of mungbean and blackgram needs to be explored in present farming system of Pothwar for increasing crop productivity and improving soil fertility. Keeping above facts in view, present trial was intended to assess the residual effect of various cropping systems and different fertility protocols on wheat under rainfed conditions of Pothwar region of Pakistan.

MATERIALS AND METHODS

The trial was carried out on inceptisol under rainfed conditions for two years (2007-08- 2008-09). %). The Pothwar plateau lies at latitude 32º 10′ to 34º 9′ N and longitude 71º 10′ to 73º 55′ E. The climate of Pothwar ranges from semi-arid to sub-humid subtropical continental. Its northern part, situated at the foot of the outer Himalayas receives greater amount of precipitation. Soil of the experimental area has low organic matter (0.5%) and alkaline in reaction (pH 8.2). Annual average rainfall is 1000 mm, 70% in monsoons during summer and remaining 30% is spread over rest part of the year (Sultani *et al.,* 2007). Before sowing, soil analyses for physical and chemical properties is given in Table I. Metrological data for rainfall, temperature and relative humidity during period of study is given in Fig 1, 2 and 3. The data was taken from water resources institute, NARC, Islamabad located on experimental site.

Five cropping systems viz: maize-wheat; mungbean-wheat; maize + mungbean-wheat; black gram-wheat and maize + blackgram-wheat and five fertility protocols viz: no fertilizer; inoculation + PK (80-60 kg. ha^{-1}); NPK (120-80-60 kg. ha^{-1}); poultry manure @ 15 t. ha^{-1} , and half poultry manure (7.5 t. ha^{-1}) + half PK (40-30 kg. ha^{-1}) + inoculation) were tested in research trial. The trial was laid out in strip block design with three replications. The cropping systems were kept in vertical blocks and fertility treatments in horizontal blocks. Poultry analysis was done (Table 7). One year old poultry manure was incorporated into soil. Three weeks before sowing poultry manure was applied in summer season. Seed inoculation: Maize seed was inoculated with PGPR and seeds of mungbean and black gram with Rhizobium strain *TAL 169*. Inoculated seeds were dried under shade and used for the sowing in the respective plots. Rhizobium and Plant Growth Promoting Rhizobacteria (PGPR) were taken from soil microbiology section, National Agriculture Research Center (NARC) Islamabad.

Full dose of inorganic fertilizer PK (80:60 kg. ha^{-1}); half dose of PK (40:30 kg. ha^{-1}) and half dose of N was applied at sowing as basal dose, while remaining N was applied at respective critical stages. Urea, single super phosphate and sulphate of Potash were used as fertilizer sources. Maize variety Islamabad Gold, mungbean (*Vigana radiata*) cultivar Chakwal Mung 97 and black gram (*Vigna mungo*) cultivar Mash 97 were planted in summer and wheat variety GA 2002 was planted in winter. Maize were planted keeping row to row distance of 90 cm while mungbean and black gram were sown at 30 cm row to row in intercropping system and at 45 cm row to row distance in sole legumes. Maize and legumes were planted on July 20, 2007 and on July 25, 2008. Wheat was planted on November 11, 2007 and November 5, 2008 in winter.

All the crops were kept free of weed infestation by employing manual hoeing whenever required. All the crops were harvested at their maturity. Maize including intercrops and wheat were threshed manually.

Harvest index (HI %) values were calculated by using the formula:

$$HI\ \% = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Soil moisture contents were determined using gravimetric methods (Hesse, 1971). Soil samples were taken in the metallic cans and weighed and dried in the oven at 105 ^{o}C for 24 hours and weights were recorded again. Soil moisture was determined by the following formula,

$$\text{Soil moisture \%} = \frac{\text{weight of fresh soil} - \text{weight of oven dried soil}}{\text{Weight of oven dried soil}} \times 100$$

Water use efficiency of maize was calculated using following formula (Gregory, 1991).

$$WUE = e / (f\text{-}g + h)$$

Where ‘e’ was grain yield (kg ha^{-1}) “f” and “g” were soil moisture contents (mm) to 30 cm depth measured at planting and at harvest, respectively and “h” was precipitation during growing season.

Statistics

Data recorded on various aspects were subjected to ANOVA analysis and treatment means was compared using Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984) by employing STAT package (Freed and Eisensmith, 1986).

RESULTS AND DISCUSSION

Different cropping systems and fertility treatments showed significant differences for grain yield of subsequent wheat. Year effect between cropping systems and different fertility treatments was also significant (Table 2). Higher grain yield of wheat was recorded in plots previously treated with sole poultry manure @15 t. ha^{-1} followed by half poultry manure + half PK + inoculation. NPK and PK + inoculation showed statistically at par yield. No fertilizer plots resulted in lower grain yield. The highest grain yield obtained after poultry manure might be attributed to balance supply of nutrients from poultry manure which improved yield components that contributed to final yield. Bodruzzaman, *et al*. (2002) reported significant increase in yields of wheat after residual effect of poultry manure following mungbean crop. Among five cropping systems, higher grain yield (3302.30 kg. ha^{-1}) of wheat was achieved in plots previously grown with mungbean which was statistically at par with that of black gram grown in preceding season. The lowest yield of wheat was recorded in plots with sole maize grown in preceding season. Wheat yield was statistically at par after maize intercropped in black gram and mungbean in previous years. Grain yield increase in the cropping systems having leguminous crops was due to improved soil moisture contents and organic matter contents and additional nitrogen fixed by legumes. Results are in conformity to the conclusions made by Shah *et al.* (2003) reported 36 % increase in wheat yields following mung bean in four years long rotation experiment in rainfed valley of Swat in Pakistan. Muhammad *et al*. (2008) reported that soybean increased the grain yield of the following wheat by 44.9 percent. Hayat *et al.* (2008) found that beans with phosphorus fertilization improved grain yield of following wheat by 20 %. Similarly, Asim *et al*. (2006) reported wheat growth, development and yield differed significantly when grown after mungbean crop. Better yield was achieved due to increased fertility because leguminous crops enriched soil through fixation of atmospheric nitrogen in their root nodules, which in turn supply residual food nutrients to the succeeding crop. Secondly, poultry manure application not only supplied residual nutrients for the following crop but also reduced the bulk density of soil. Mbah and Onweremadu (2009) concluded that on the average, poultry droppings gave the highest grain yield by improving aggregate stability and reducing bulk density indicating that these parameters contributed to final grain yield. The minimum wheat yield after non legume maize was due to the fact that maize being an aggressive feeder depleted the nutrients from soil and reduced supply of plant nutrients in the no fertilizer plots which were already deficient in nutrients. It seems logical, that subsequent wheat would give minimum yield.

Table 1. Physico-chemical analyses of the soil samples from experimental site.

Determinations	Values
ECe d S m^{-1}	0.25
pH	8.35
Organic matter (%)	0.63
Sand (%)	62
Silt (%)	12
Clay (%)	26
Textural class	Sandy-clay loam
Bulk density (g cm^{-3})	1.47
Available P (mg kg^{-1})	6.76
Extractable K (mg kg^{-1})	74.31
Nitrate-N (mg kg^{-1})	3.85
Total N (%)	0.032

Table 2. Effect of different fertility treatments and cropping systems on grain yield of subsequent wheat (kg ha^{-1}).

Cropping systems	2007-08	2008-09	2-Year mean
Sole maize	2819.03	2977.87	2898.45 c
Sole mungbean	3228.26	3318.43	3273.34 a
Maize + mungbean	3042.92	3202.70	3122.81 b
Sole mash bean	3215.85	3388.75	3302.30 a
Maize + mash bean	3006.38	3256.56	3131.47 b
LSD			60.10
Fertility protocols			
No fertilizer	2802.67	2800.50	2801.59 d
PK + inoculation	2887.93	3218.13	3053.03 c
NPK	3049.46	3155.04	3102.25 c
Poultry manure (PM)	3413.16	3558.09	3485.62 a
Half PM + half PK+ inoculation	3159.21	3412.57	3285.89 b
LSD			108.70
Means over Years	3062.49 b	3228.86 a	

* Means sharing a common letter within a column or a row did not differ significantly at 5 % probability level

Table 3. Effect of different fertility treatments and cropping systems on biological yield of subsequent wheat (kg ha^{-1}).

Cropping systems	2007-08	2008-09	2-Year mean
Sole maize	8029.91	8054.12	8042.02 c
Sole mungbean	8767.25	8614.78	8691.02 a
Maize + mungbean	8519.96	8544.41	8532.18 ab
Sole mash bean	8664.55	8746.64	8705.60 a
Maize + mash bean	8232.77	8512.67	8372.72 b
LSD			183.00
Fertility protocols			
No fertilizer	8092.37	7588.62	7840.50 c
PK + inoculation	8063.75	8606.48	8335.11 b
NPK	8457.53	8352.28	8404.91 b
Poultry manure (PM)	8925.21	8740.72	8832.96 a
Half PM + half PK+ inoculation	8675.58	9184.52	8930.05 a
LSD			276.00
Means over Years	8442.89	8494.52	

* Means not sharing a common letter in a column or a row had significant effect at 0.05 P

Biological yield of wheat was affected significantly by different cropping systems and fertility treatments. The year effect and interactions between cropping systems and different fertility treatments were non significant. Biological yield of wheat was increased in fertilized plots as compared to no fertilizer. The highest biological yield was recorded with poultry manure + half PK+ inoculation treatment that were followed by NPK. The combination of poultry manure, chemical fertilizers and inoculation had pronounced effect on soil fertility and moisture conservation that resulted in better vegetative growth in terms of leaf area index, plant height and total dry matter (Table 3). Among cropping systems, it was noted that higher biological yield of wheat (8705.60 kg. ha^{-1}) was recorded after blackgram that was statistically at par with mungbean (8691.02 kg. ha^{-1}) grown in preceding seasons. Minimum yield was observed in plots after maize in preceding seasons. Maize intercropped with blackgram and mungbean in previous year gave statistically equal wheat biological yield of 8372.72 kg. ha^{-1} and 8532.18 kg. ha^{-1} respectively.

These results were in agreement with the findings of many scientists like Ryan *et al.* (1997) and Aslam *et al.* (2003). They concluded that the legume rotation had a strong and consistent effect on total biomass production of wheat.

Table 4. Effect of different fertility treatments and cropping systems on harvest index HI (%) of subsequent wheat

Cropping systems	2007-08	2008-09	2-Year mean
Sole maize	35.12	36.94	36.03 c
Sole mungbean	36.76	38.49	37.62 a
Maize + mungbean	35.71	37.50	36.61bc
Sole mash bean	37.05	38.76	37.91 a
Maize + mash bean	36.51	38.27	37.39 ab
LSD			0.92
Fertility protocols			
No fertilizer	34.66	36.88	35.77 c
PK + inoculation	35.81	37.39	36.60 bc
NPK	36.05	37.78	36.91 b
Poultry manure (PM)	38.19	40.70	39.45 a
Half PM + half PK+ inoculation	36.44	37.22	36.83 b
LSD			0.81
Means over Years	36.23 b	37.99 a	

Means sharing a common letter within a column or a row did not differ significantly at 5 % probability level

Table 5. Effect of different fertility treatments and cropping systems on water use efficiency (kg. ha^{-1} mm^{-1}) of subsequent wheat.

Cropping systems	2007-08	2008-09	2-Year mean
Sole maize	6.14	8.82	7.48 c
Sole mungbean	7.09	9.89	8.49 b
Maize+ mungbean	7.35	9.38	8.36 b
Sole mash bean	7.95	10.82	9.39 a
Maize + mash bean	7.12	9.75	8.43 b
LSD			0.36
Fertility protocols			
No fertilizer	9.27	6.78	8.03 b
PK + inoculation	9.90	7.09	8.50 a
NPK	9.78	7.27	8.53 a
Poultry manure (PM)	9.83	7.32	8.57 a
Half PM + half PK+ inoculation	9.87	7.19	8.53 a
LSD			0.36
Means over Years	7.13 b	9.73 a	

* Means sharing a common letter within a column or a row did not differ significantly at 5 % probability level

Harvest index % of wheat was significantly affected by different cropping systems and fertility treatments tested in preceding summer. The year effect and interactions between cropping systems and different fertility treatments was significant. Highest harvest index of wheat (39.45%) was recorded in plots previously treated with sole poultry manure followed by NPK application with the HI of 36.91%. Sole poultry application @ 15 t. ha^{-1} and half poultry manure + half PK + inoculation showed statistically similar harvest index. Minimum harvest index (35.77 %) was observed in no fertilizer treatment. The highest harvest index obtained was due to efficient utilization of nutrients and soil moisture which increased rate of conversion of dry matter into economic yield in sole poultry application @

15 tha^{-1} application and half poultry manure + half PK+ inoculation treatments (Table 4). Secondly, better grain yield in above mentioned treatments contributed to higher harvest index of wheat. Among cropping systems higher harvest index of wheat (37.91%) was recorded in plots previously grown with blackgram which was statistically at par with sole mungbean (37.62 %) grown in the preceding seasons. After maize minimum harvest index of wheat (36.03 %) was observed. Wheat preceded maize intercropping with blackgram and mungbean gave statistically equal wheat harvest index. The harvest index of wheat was enhanced after both the legumes. Thus, it is proving that inclusion of either sole legumes or as intercrops with cereals is superior combination than the sole maize.

Table 6. Effect of different fertility treatments and cropping systems on soil moisture contents (cm) at harvest.

Cropping systems	0-30 cm	30-60 cm	60-90 cm	0-90 cm
Sole maize	3.06 c	4.30 c	4.51 c	11.88 c
Sole mungbean	3.74 a	5.08 a	5.26 ab	14.09 a
Maize + mungbean	3.45 b	4.85 b	5.09 b	13.40 b
Sole mashbean	3.80 a	5.14 a	5.36 a	14.30 a
Maize + mashbean	3.32 b	4.74 b	5.11 b	13.18 b
LSD	0.15	0.19	0.20	0.51
Fertility protocols				
No fertilizer	3.39 c	4.68 c	4.95 b	13.03 c
PK + inoculation	3.47 ab	4.79 b	5.04 ab	13.31 bc
NPK	3.45 bc	4.82 b	5.08 ab	13.36 b
Poultry manure (PM)	3.55 a	4.95 a	5.16 a	13.67 a
Half PM + half PK+ inoculation	3.50 ab	4.87 ab	5.11 a	13.48 ab
LSD	0.09	0.10	0.13	0.28

* Means sharing a common letter within a column or a row did not differ significantly at 5 % probability level

Table 7. Nutrient composition of the poultry manure used in the study.

Determinations	Units	Values	
		2007	2008
Nitrogen	%	0.78	0.75
Phosphorus	%	0.61	0.63
Potassium	%	0.43	0.41
Dry matter	%	58	52
Moisture	%	42	48

Water use efficiency of wheat varied significantly by year, different cropping systems and fertility treatments. The water use efficiency was improved by use of various fertilizers against no fertilizer but the treatments did not differ significantly among them. Higher water use efficiency of wheat (8.57 kg. ha^{-1} mm^{-1}) was recorded in plots treated with sole poultry manure @15 t. ha^{-1} and the minimum water use efficiency (8.03 kg. ha^{-1} mm^{-1}) was observed in non treated plots. On an average basis, 26 % higher water use efficiency of wheat in 2009 than 2008 (Table 5). The improvement in water use efficiency in 2009 is attributed to better growing season. The highest water use efficiency was due to balanced supply of nutrients. Among the cropping systems, maximum water use efficiency (9.39 kg. ha^{-1} mm^{-1}) was recorded after sole blackgram followed by sole mungbean (8.49 kg. ha^{-1} mm^{-1}). Minimum water use efficiency (7.48 kg. ha^{-1} mm^{-1}) was observed in sole maize plots in preceeding summer season. Maize intercropped in blackgram and mungbean in previous season gave statistically similar water use efficiency for wheat (8.43 kg. ha^{-1} mm^{-1}) and (8.36 kg. ha^{-1} mm^{-1}), respectively. Results were in line with the findings made by Hayat *et al.* (2008) who reported that after mungbean and blackgram water use efficiency of wheat was improved than sorghum.

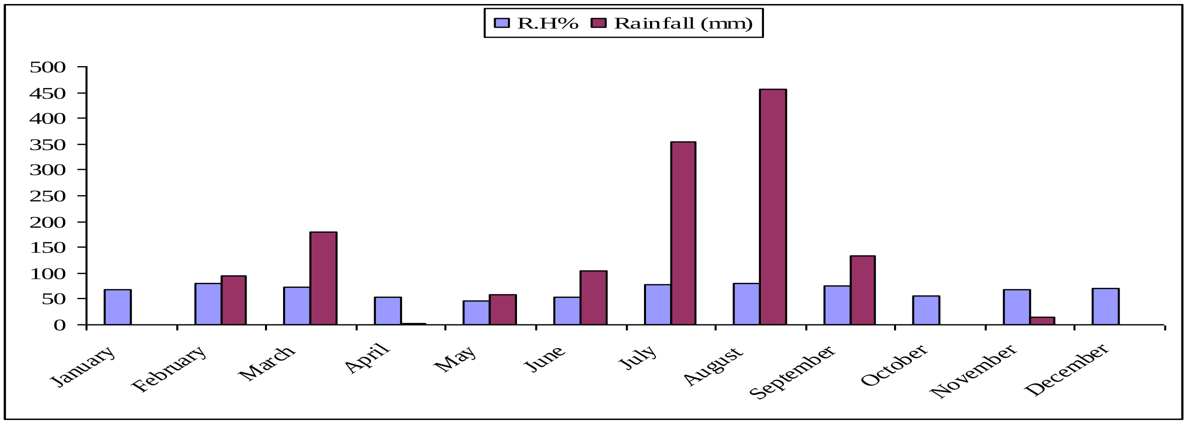

Fig.1. Rainfall and relative humidity data during growing season 2007.

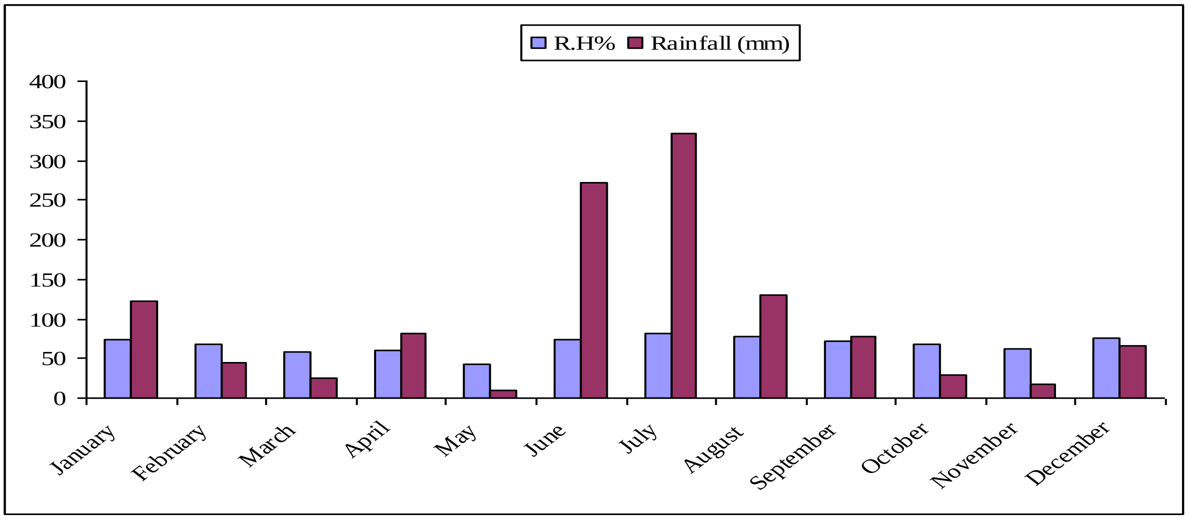

Fig.2. Rainfall and relative humidity data during growing season 2008.

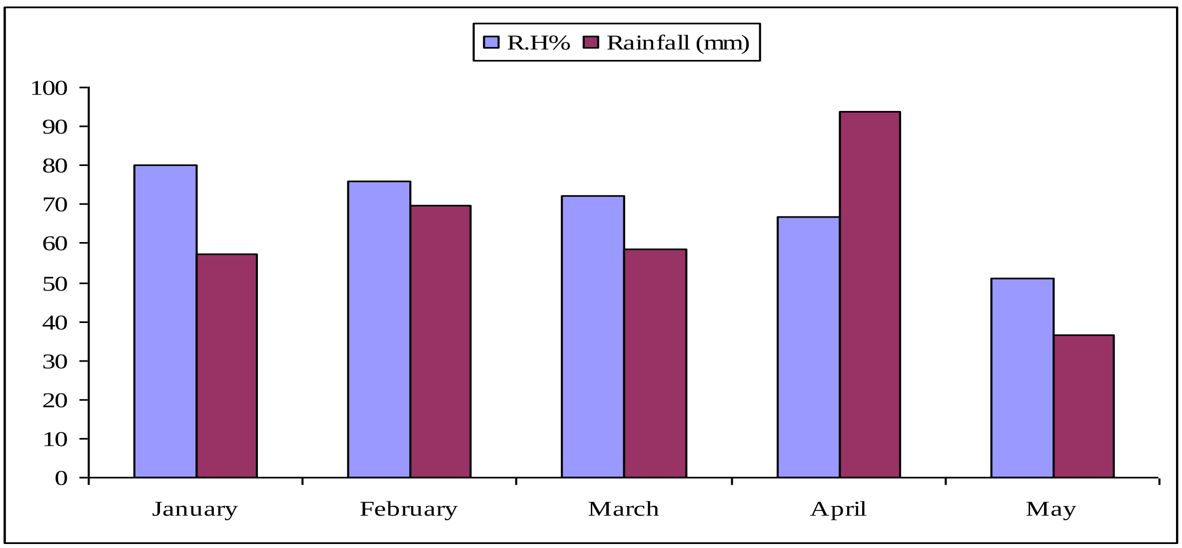

Fig.3. Rainfall and relative humidity data during growing season 2009.

Different cropping systems affected moisture contents of soil under various fertility treatments (Table 6). Maximum moisture contents of soil (14.30 cm) were recorded in plots after blackgram which was statistically equal to mungbean grown in preceding summer season. Minimum moisture contents of soil (11.88 cm) were observed maize- wheat in sequence. Higher moisture contents were observed in 60-90 cm soil profile. Results are in conformation with the findings of Hayat *et al. (*2008). Higher water contents of soil **(**13.67 cm) were noted in plots previously treated with sole poultry manure. Minimum moisture contents (13.03 cm) were recorded in plots receiving none of the treatments. Similarly, Agbede *et al*. (2008) found that poultry manure significantly reduced soil bulk density, temperature and enhance porosity and soil moisture contents.

CONCLUSION

Wheat yield increased significantly after blackgram and mungbean than wheat grown after maize. Higher water use efficiency of wheat and soil moisture contents in different soil profile were recorded after legumes. Similarly, more wheat yield and water use efficiency was recorded after poultry manure. By including legumes in crop rotation, soil productivity and fertility could be enhanced. Hence, legume-cereal (blackgram-wheat) cropping sequence with poultry manure proved to be more productive and sustainable than cereal-cereal (maize-wheat) rotation.

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