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WATER EFFICIENT CROPPING SYSTEMS FOR SEMI-ARID REGIONS IN PAKISTAN

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ABSTRACT. Water scarcity and land degradation are emerging threats to global food production. The dry land regions of world are affected by climate change to a greater extent and facing food insecurity. The current pattern of food production has been estimated to be inadequate to meet demands of growing population and required around 38% increase to meet world`s food demands by 2025. Food insecurity in erosion hit dry land regions of Pakistan also demands development of resource-efficient cropping systems to meet the food needs of population growing. The research studies involved different cropping patterns such as fallow-wheat, mungbean-wheat, sorghum-wheat, fallow-lentil, mungbean-lentil, sorghum-lentil, fallow-barley, mungbean-barley and sorghum-barley. The organic amendments involved farmyard manure, NPK, poultry manure, compost and inoculation by phosphorus solubilizing microbes. The effect of cropping systems and soil amendments were evaluated at field scale in terms of water use efficiency measured in terms of economic terms. The results of the studies revealed that double cropping (mungbean-lentil and mungbean-barley) was feasible option in the dryland regions of Pakistan if integrated with the use of poultry manure as alternate environmental-friendly strategy to cut down the use of mineral fertilizers and eliminate summer fallowing.

Key words: Water use efficiency; Mineral fertilizers; Soil amendments; Cropping systems; Dry lands.

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INTRODUCTION

Water scarcity and land degradation are major challenges to food production in dry land regions of world. The current pattern of food production has been estimated to be inadequate to meet demands of growing population and required around 38 % increase to meet world`s food demands by 2025 (Seckler *et al*., 1999). Dryland region in Pakistan cover an area of around 4 million ha (Anonymous, 2012) face similar challenges but are considered un-explored to greater extent and can contribute substantial increase in food production provided nutrient and water efficient crop production practices are developed and adopted by farming communities (Khan and Qayyum, 1986). The irrigated food basket has been utilized to full potential and only marginal increases can be expected. The dryland areas are food insecure on account of exhaustive cropping systems accompanied with soil erosion problem and poverty (Arif and Malik, 2009). Cereal-based cropping systems dominate with respect to area in the region (Sheikh *et al*., 1998). Moreover, the trend of growing continuous cereals (fallow-wheat) on arable lands has further depleted the nutrient in the soil that is already low (Rashid and Qayyum, 1994). The prevalence of soil erosion has been depleting the productive capacity of soils. The prices of mineral fertilizers have gone beyond the reach of small farmers, therefore, alternate water and nutrient efficient cropping systems need to be developed to improve livelihood of rural farming communities. Inclusion of legumes in the cropping system is considered an effective strategy (Ali *et al*., 2002; Gyaneshwar *et al.,* 2002; Huang and Shao, 2003) with the use of organic amendments (Warren *et al*., 2006) such as farmyard manure and poultry manure, compost to improve soil organic matter, soil structure, enhance nutrients and water holding capacity of the soil, which ultimately result in higher economic returns (Huang and Shao, 2003). Organic amendments effectively recycled nutrients and improved nutrient supply to crops (Warren *et al*., 2006), improved water use efficiency (Nielsen *et al*., 2005) and were utilized for improved farm production as alternate of synthetic fertilizers. The integration of phosphorus solubilizing microbes (PSB) was found to further promote crop growth by production of plant growth promoting substances (Gyaneshwar *et al*., 2002). Such syntrophic relations are of environmental significance with oblique agricultural importance.

The integration of cropping systems with organic amendments may help to develop water and nutrient efficient cropping systems, therefore, a comprehensive study was conducted to evaluate the effect of organic amendments and inorganic fertilizers under different cropping sequence on water use efficiency (WUE) in economic terms.

MATERIALS AND METHODS

The experiments were conducted at University Research Farm, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi (Pakistan) under rainfed conditions. The site situated in subtropical continental semi-arid climatic zone characterized by long hot summers and mild winters. Soil of the area was inceptisol and loess in nature, slightly alkaline with pH 8.2, having low organic matter about (0.5%). Average maximum temperature ranges from 97 to 107 ºF (36º to 42ºC) - with extremes sometimes as high as 118ºF (48ºC) during June and July. Contrarily, December and January are the coldest months, with mean minimum temperatures of about 38º to 42ºF (3º to 5.5ºC). Occasionally, the lowest minimum temperature may drop to 26 ºF (-3.3ºC). Usually, frost occurs during some days of November to February.

The research studies were conducted with following sets of experimental units:

1. Cropping sequences

Set I

CS1	fallow-wheat
CS2	mungbean-wheat
CS3	sorghum-wheat

Set II

CS4	fallow-lentil
CS5	mungbean-lentil
CS6	sorghum-lentil

Set III

CS7	fallow-barley
CS8	mungbean-barley
CS9	sorghum-barley

2. Organic/Inorganic soil amendments

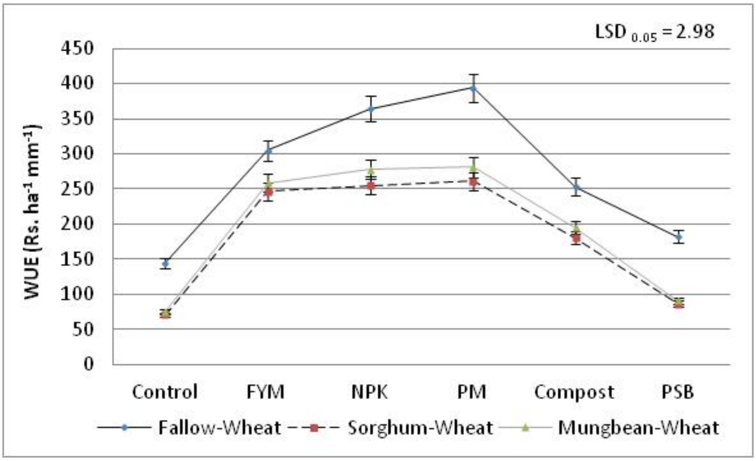
T_0 = Control
T_1 = farmyard manure (FYM) @ 30 tons ha^{-1}
T_2 = NPK at recommended dose for each crop
T_3 = poultry manure (PM) @ 20 tons ha^{-1}
T_4 = compost @ 12.5 tons ha^{-1}
T_5 = inoculation by PSB @ 2.5 packets ha^{-1}

The influence of five different organic and inorganic treatments in different cropping patterns was evaluated on the basis of water use efficiency using RCBD with split-plot arrangement of treatments. Subplot size was kept 3x5 m. The experiments were conducted from 2007 to 2009. All the other agronomic practices were kept as per recommendations of the respective department of agriculture. Water use efficiency was calculated following procedure adopted by (Chen *et al.,* 2003). The crop yield in each experimental unit at harvest was multiplied with its market value to have water use efficiency in economic terms truly representing farmers perspective.

RESULTS

Water use efficiency of wheat under different cropping systems

The results (*Fig. 1*) revealed significantly higher WUE of wheat with the use of poultry manure (PM) and it was followed by NPK, FYM, compost and PSB. Maximum water use efficiency (Rupees ha^{-1} mm^{-1}) was observed in fallow land (273.64) of wheat, followed by wheat-mungbean cropping sequences (196.42) followed by decreasing trend with significant differences in wheat-sorghum cropping sequences (183.22). PM-wheat-fallow land interaction showed higher respond to WUE (Rs. ha^{-1} mm^{-1}) as compared to NPK-wheat-fallow land and FYM-wheat-fallow land cropping sequences with significant differences. In case of PM-wheat-mungbean interaction for water use efficiency was higher than NPK-wheat-mungbean with significant differences, while lowest interaction for WUE (Rs. ha^{-1} mm^{-1}) was measured in control-wheat-sorghum cropping sequence.



FYM= farm yard manure; NPK= nitrogen phosphorus and potassium; PM= poultry manure; PSB= phosphorus solubilizing bacteria

Figure 1 - Economic water use efficiency under wheat-based cropping systems and different soil amendments

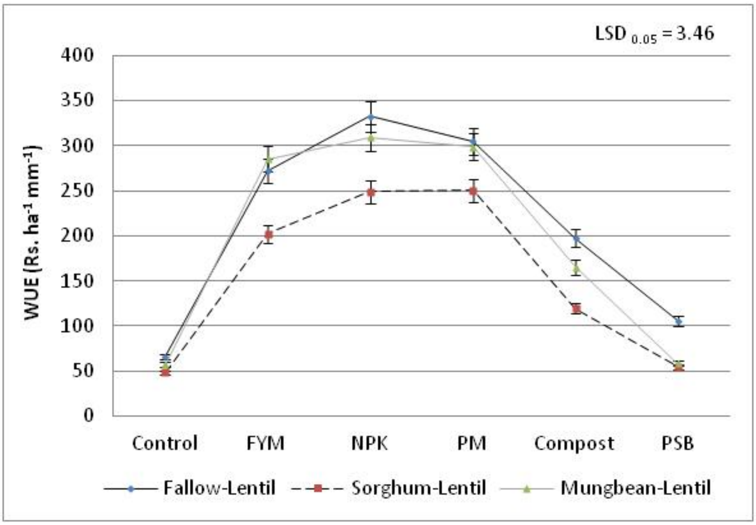
Water use efficiency (Rs. ha^{-1} mm^{-1}) on the basis of fertilizer treatments was observed higher in 2007-‘08 fallow land cropping sequence, treated with PM (394.11), followed by wheat-mungbean in 2008-‘09 (280.83) with significant differences, followed by wheat-sorghum cropping sequences (260.85) with significant differences, same trend was observed in case of NPK, FYM, compost, PSB and control.

Water use efficiency of lentil under different cropping systems

WUE was observed (*Fig. 2*) higher in NPK, followed by PM, FYM, compost and PSB with significant differences. Maximum water use efficiency (Rs. ha^{-1} mm^{-1}) was observed in fallow land (213.07) of lentil, followed by lentil-mungbean cropping sequences (195.56), followed by decreasing trend with significant differences in lentil-sorghum cropping sequences (153.91). NPK-lentil-fallow land cropping sequence showed higher respond to WUE (Rs. ha^{-1} mm^{-1}) as compared to NPK-lentil-mungbean, followed by PM-lentil-fallow land with significant differences. In case of PM-lentil-mungbean showed higher interaction for water use efficiency than FYM-lentil-mungbean cropping sequence with significant difference. Lowest interaction for

WUE (Rs. ha^{-1} mm^{-1}) was measured in control-lentil-sorghum.

Water use efficiency (Rs. ha^{-1} mm^{-1}) on the basis of fertilizer was observed higher in 2007-'08 fallow land cropping sequence, treated with NPK (332.53), followed by lentil-mungbean in 2008-'09 (308.89) with significant differences, followed by lentil-sorghum cropping sequences (248.93) with significant differences, same trend was observed in case of PM, compost, PSB and control, while in case of FYM maximum WUE (Rs. ha^{-1} mm^{-1}) was observed in lentil-mungbean cropping-sequence in 2008-'09, followed by fallow land and lentil-sorghum in 2008-'09 with significant differences.



FYM= farm yard manure; NPK= nitrogen phosphorus and potassium; PM= poultry manure; PSB= phosphorus solubilizing bacteria

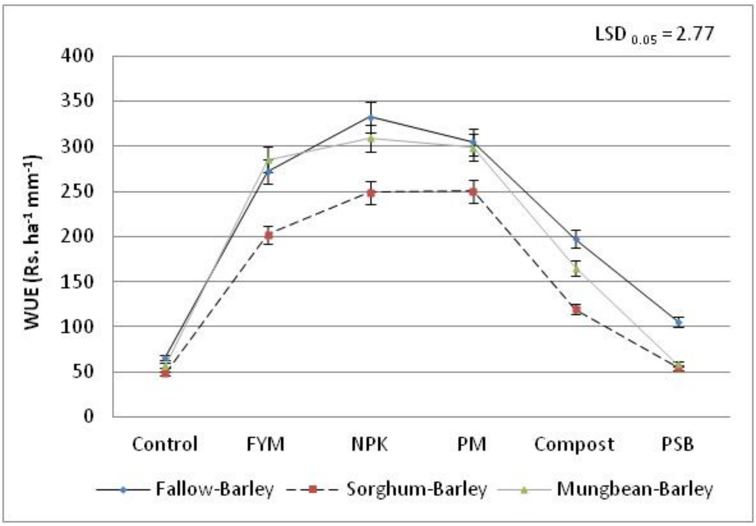
Figure 2 - Economic water use efficiency under lentil-based cropping systems and different soil amendments

Water use efficiency of barley under different cropping systems

The *Fig. 3* showed higher WUE in NPK, followed by PM, FYM, compost and PSB with significant differences. All fertilizers treatments were significant than control. Maximum water use efficiency (Rs. ha^{-1} mm^{-1}) was observed in fallow land (145.96) of barley followed by in barley-mungbean cropping sequences (106.25), followed by decreasing trend with significant differences in barley-sorghum cropping sequences (83.97). NPK-barley-fallow land interaction showed higher response to WUE (Rs. ha^{-1} mm^{-1}), followed by FYM-barley-fallow land and PM-barley-fallow land with significant differences. In case of NPK-barley-mungbean interaction gave significant response to water use efficiency than

NPK-barley-sorghum, while PM-barley-mungbean cropping sequence and fertilizer interaction respond significantly than FYM-barley-mungbean.

Water use efficiency (Rs. ha^{-1} mm^{-1}) on the basis of fertilizer treatments was observed higher in 2007-'08 fallow land cropping sequence, treated with NPK (229.20), followed by barley-mungbean in 2008-'09 (172.11) with significant differences, followed by barley-sorghum cropping sequences (147.59) with significant differences, same trend was observed in PM, FYM, PSB and control. In case of compost water use efficiency was maximum for fallow land 2007-'08, followed by barley-mungbean with non-significant differences and barley-sorghum with significant differences.



FYM= farm yard manure; NPK= nitrogen phosphorus and potassium; PM= poultry manure; PSB= phosphorus solubilizing bacteria

Figure 3 - Economic water use efficiency under barley-based cropping systems and different soil amendments

DISCUSSION

The Pothwar plateau lies at latitude 32º10′ to 34º9′ N and longitude 71º10′ to 73º55′ E. Rainfall is erratic and varies greatly from 1,000 mm in the northeast to 250 mm in the southwest, 70% of which is received during summer monsoons while rest of 30% is distributed in remaining part of the year mostly from December and March. The skewed rainfall pattern causes early season drought which affects growth and development of crops during early growth period leading to lower crop productivity. The experimental data showed that the under dryland conditions, cropping systems involving summer fallow were more remunerative and were followed by legume based cropping systems. However, the response of different soil amendments was variable with cropping systems. The higher economic water use efficiency under poultry manure may be attributed to the common farmers' practice adding poultry manure after every 2-3 years in the soils leading to improved soil fertility that lead to improved crop productivity. The findings are in accordance with studies of Ghosh *et al.* (2004), who reported improved phosphorus availability under poultry manure lead to improved crop growth as compared to any other manure. Roy and Prasad (2004) also reported that organic manures like poultry manure and farmyard manure can be utilize for farm production as alternate of synthetic fertilizers. The higher economic WUE under lentil and barley based cropping systems under NPK fertilization may be attributed to higher availability of nutrients and drought tolerance of these crops which resulted in enhanced crop productivity. The data revealed that double cropping (mungbean-lentil and mungbean-barley) was feasible option in the dryland regions of Pakistan if integrated with the use of poultry manure as alternate environmental-friendly strategy to cut down the use of mineral fertilizers and eliminate summer fallowing. The results are supported by findings of Eghball *et al.* (2002), who reported that integration of suitable cropping systems with fertilizers contributed for higher yield, more profit and healthy soils.

CONCLUSION

It was concluded that double cropping (mungbean-lentil and mungbean-barley) was feasible option in the dryland regions of Pakistan if integrated with the use of poultry manure as alternate environmental-friendly strategy to cut down the use of mineral fertilizers and eliminate summer fallowing.

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