Field Crops Research 219 (2018) 214–221

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Increasing farmer's income and water use efficiency as affected by long-term fertilization under a rainfed and supplementary irrigation in a soybean-wheat cropping system of Indian mid-Himalaya

Suresh Chandra Panday, Mahipal Choudhary, Sher Singh, Vijay Singh Meena*, Dibakar Mahanta, Ram Prakash Yadav, Arunava Pattanayak, Jaideep Kumar Bisht

ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS), Almora, 263601, Uttarakhand, India

ARTICLE INFO

Keywords:
FYM
Net returns
Rainfed
Supplementary irrigation
Water use efficiency (WUE)
Water expense efficiency (WEE)

ABSTRACT

Water and nutrient management are major corners in the improvement of productivity and sustainability of rainfed soybean-wheat cropping systems (SWCS). A nine-year-old (2006–2014–15) field experiment was started to explore the effects of recommended dose of farm yard manure (FYM) in SWCS, recommended dose of nitrogen, phosphorus and potassium fertilizers (RDF) along with FYM, FYM + 50% NPK, NPK, $FYM_{soybean}$ + NPK_{wheat} and without application of NPK and FYM (CK) under rainfed (I_0) and supplementary irrigation (I_1) situation in SWCS. Results from nine years continuous fertilization of NPK + FYM showed significantly highest grain yield of wheat (2.70 and 3.80 t ha^{-1}) and soybean (2.50 and 2.74 t ha^{-1}) under rainfed (I_0) and supplementary irrigation (I_1), respectively as compared to rest of treatments. Significant ($p < 0.05$) correlation ($R^2 = 0.50$) was observed between seasonal rainfall and wheat grain yield. However, SWCS yield was also significantly ($p < 0.05$) higher with fertilization of NPK + FYM plots under both rainfed (I_0) and supplementary irrigation (I_1) situation. The mean water use efficiency (WUE) of wheat (9.70 and 9.60 kg ha^{-1} mm^{-1}) was significantly higher as compared soybean (3.8 and 4.3 kg ha^{-1} mm^{-1}) under rainfed (I_0) and supplementary irrigation (I_1), respectively. Meanwhile, in respective of treatments WUE of wheat (15 and 14 kg ha^{-1} mm^{-1}) and soybean (5.7 and 6.2 kg ha^{-1} mm^{-1}) were significantly ($p < 0.05$) higher in NPK + FYM plots under rainfed (I_0) and supplementary irrigation (I_1), respectively. Results showed that grain yield, irrigation and fertilizer interaction was significant ($p < 0.05$) positive for wheat, whereas it was non-significant for soybean. The net returns were significantly higher with fertilization of NPK + FYM under rainfed (I_0) and supplementary irrigation (I_1) in SWCS. Economic efficiency (EE) and production efficiency (PE) was also significantly ($p < 0.05$) higher with NPK + FYM fertilization in SWCS. Thus, we conclude that in the long-term fertilization (NPK + FYM) in SWCS under rainfed and supplementary irrigation situation, respectively is sustainable option for higher economic as well as production efficiency.

1. Introduction

Rainfed agriculture covers ~80% of the world's cultivated land, and contributes ~60% to the total crop production (UNESCO, 2009). Irrigation and fertilization are the two important inputs in obtaining high grain yields and sustainability around the world (Bernacchi and VanLoocke, 2015; Liang et al., 2016; Sharma et al., 2017). The mountains are considered as water towers of earth, but they face acute shortage of water not only during lean period but also in rainy season. Soil moisture conservation is a critical issue in rainfed farming in sub-temperate regions of the Indian Himalayas (Bhattacharyya et al., 2010). The syndrome of water surplus and deficit also exist in Indian mid-Himalayas. In *kharif* season there is high intensity surplus rainfall causing intensive erosion, reduces both the soil organic carbon (SOC) content and plant nutrients while deficit causes drought during wheat are main feature of Indian mid-Himalayas agriculture. The agriculture is a main occupation of ¾ populations of Indian Himalayas and ~90% area under rainfed agriculture. The higher mountains have very meager sources of water (water springs) which are mostly used for drinking purpose and there is no source for agricultural use. The irrigation water is inadequate in valley and farmers get rivers water diverted through small canals known as gulls. The fertilizer supply in hills is also limited and transportation of fertilizers from plains is very costly.

The rainfed agriculture system of Indian mid-Himalaya has yields of

* Corresponding author.
E-mail addresses: vijayssac.bhu@gmail.com, vijay.meena@icar.gov.in (V.S. Meena).

https://doi.org/10.1016/j.fcr.2018.02.004
Received 12 July 2017; Received in revised form 3 January 2018; Accepted 6 February 2018

Table 1
Mean climatic parameter during crop growth period (2006–2015).

Months	Maximum Temperature (°C)	Minimum Temperature (°C)	Evaporation (mm day^{-1})	Rainfall (mm)
	Kharif (soybean) season			
June	31.2	18.12	3.7	133.9
July	28.8	20.96	2.4	215.3
August	28.9	20.64	2.6	201.8
September	29.1	18.15	2.9	141.8
October	27.3	10.79	2.6	27.2
	Rabi (Wheat) season			
November	24.0	4.39	1.8	3.4
December	20.7	0.12	1.3	18.2
January	18.9	0.12	1.1	23.1
February	20.5	2.66	1.4	61.2
March	24.5	6.17	2.2	27.2
April	28.4	9.38	3.2	33.5

1.0 and 1.5 t ha^{-1} for wheat and soybean, respectively. However, the farmers of the region getting only ~60% of the potential yield of the used crop varieties (Bhattacharyya et al., 2016). Low productivity in many rainfed agricultural systems is often due to degraded soil fertility and limited water and nutrient inputs at the time of critical crop growth stages (Mueller et al., 2012; Qin et al., 2015). A judicious and combined use of mineral fertilizer and organic manure is essential for sustaining higher crop yields, soil health and to augment the efficiency of nutrients (Jaga and Upadhyay, 2013; Sikka et al., 2013; Qin et al., 2015). Additionally, such integration of organic and mineral fertilizers plays vital role in better penetration and establishment of crop roots, which helps the plant to utilize water from deeper layers and to maintain high relative plant water content under a soil moisture stress condition, which is quite common in rainfed agriculture (Sharma et al., 2017; Singh et al., 2017). Hence, irrigation is the basic need for the agriculture sector but its injudicious use results in large consumption of green and blue water required for this sector (Rost et al., 2008; Atheefa et al., 2016).

Water availability for agricultural production system is a precious commodity and there is an urgent need to organize the irrigation scheduling in crops for improving WUE in this region. Increasing WUE ~40% on rainfed and irrigated lands would be required to compensate the need for additional withdrawals of irrigation over next 25 years to meet additional demand for food (Singh et al., 2010). Bhatt et al. (2016) reported that ~35–55% of irrigation water was lost before reaching the main field. Thus, low WUE is the challenge in way for sustainable agriculture and could be improved by water-saving agriculture and water-saving irrigation technologies viz. use of FYM, green manure, mulching, reduced evapotranspiration losses, including low pressure irrigation, furrow irrigation, drip irrigation, cementing the water channels/courses to reduce percolation losses, laser land leveling, irrigation based on soil matrix potential using tensiometers etc. (Deng et al., 2006). Therefore, our research focused on finding out a sustainable way to use harvested runoff water as supplementary irrigation under rainfed SWCS in the Indian mid-Himalayan to enhance profitability and productivity with the help of judicious fertilization. In this study, we hypothesized that long-term mineral and organic fertilization in supplementary irrigation as well as rainfed SWCS would significantly increase farm productivity and profitability. The objective of the study was to quantify (i) how long-term effects of fertilization under rainfed and supplementary irrigation conditions on crop yield over time; (ii) to examine rainfall and fertilization interactions in crop yield and (iii) water use efficiency and economic efficiency as influenced by different treatments under rainfed and irrigations under SWCS in the Indian mid-Himalayas conditions.

2. Materials and methods

2.1. Experimental site

The investigation was conducted by establishing a field experiment in 2006 on coarse loamy sandy soils at the experimental farm of the ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS), Hawalbagh (29°36′N; 79°40′E at 1250 m above sea level) Almora, Uttarakhand, India. The climate of the experimental area is sub-temperate, characterized by moderate summer (May-June), a spell of chilling winter (December-January), and general dryness, except during the south-west monsoon season (June-September). The mean annual rainfall of crop growth period during the nine-years of experiment (2006–2014–15) was ~935 mm. General climatic parameters shown in Table 1.

2.2. Experimental design and treatments

In the present investigation soybean (June-September) and wheat (October-April) cropping system was followed with twelve (number) treatment combinations. Six combinations of mineral fertilizer and manures as given in Table 2 were provided to SWCS. These six fertilizer combinations were kept in two situations; first is supplementary irrigation (I_1) {(i) in wheat a total of 100 mm in two splits of 50 mm at 15 days after sowing (DAS) and at flowering (ii) in soybean @ 50 mm whenever continuous 15 days dry spell occurred} and second is rainfed (I_0) situation. The experiment was laid out in Factorial Randomized Block Design (FRBD) with four replications in each treatment.

2.3. Crop management

Mineral N, P and K fertilization was applied as urea, di-ammonium phosphate (DAP) and potassium chloride (MOP), respectively. Nitrogen was applied in two equal splits at the time of field preparation, and after 45 DAS (Table 2). The gross plot size was 9 m^2 (3.0 m × 3.0 m). All plots were manually ploughed to ~20 cm depth after each harvest and

Table 2
Treatments' details of SWCS under rainfed (I_0) and supplementary irrigation (I_1) conditions of Indian mid-Himalaya.

Treatments	Treatment description	Treatment notations	Fertilizers application	
			Wheat	Soybean
T_1	No fertilizer and manure to both crops (soybean and wheat)	CK	0−0−0	0−0−0
T_2	FYM (10 t ha^{-1}) to both crops	FYM	FYM (10 t ha^{-1})	FYM (10 t ha^{-1})
T_3	Recommended dose of NPK + FYM to both crops	NPK + FYM	NPK (100-26–33 kg ha^{-1}) + FYM (10 t ha^{-1})	NPK (20–35–33 kg ha^{-1}) + FYM (10 t ha^{-1})
T_4	Half dose of mineral fertilizer NPK + FYM to both crops	FYM + 50% NPK	50% NPK (50-13-16.5 kg ha^{-1}) + FYM (10 t ha^{-1})	50% NPK (10–17.5-16.5 kg ha^{-1}) + FYM (10 t ha^{-1})
T_5	Recommended dose of NPK to both crops	NPK	NPK (100-26–33 kg ha^{-1})	NPK (20–35–33 kg ha^{-1})
T_6	Recommended dose of NPK in wheat + FYM in soybean season	FYM_S + NPK_W	NPK(100-26–33 kg ha^{-1})	FYM (10 t ha^{-1})