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VARIATION IN CROP YIELD IN RICE-WHEAT DRYLAND AGROECOSYSTEM : IMPACT OF VARYING RESOURCE QUALITY INPUTS

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Abstract

Maximizing crop yield is the major objective of all agricultural management strategies, yet environmental sustainability of agroecosystems has become a major global concern. Two year study was conducted to evaluate the impact of application of exogenous soil inputs of varying resource quality on crop yield under rice-wheat-summer fallow crop sequence in tropical dryland agroecosystem. All the exogenous inputs were designed to contain equivalent amount of N (80 Kg ha^{-1}) and the treatments were: (1) *Sesbania* shoot, high quality resource (SS); (2) wheat straw, low quality resource (WS); (3) *Sesbania* + wheat straw, mixed quality resource (WS+SS); (4) Chemical Fertilizer (CF) and Control, no input (CO). At the end of the second annual cycle, maximum rice yield was found in CF followed in decreasing order by SS, WS + SS, WS and lowest in CO. However, in succeeding wheat crop, unlike rice yield, maximum wheat yield was recorded in WS, followed in decreasing order by WS + SS, CF, SS and lowest in CO. The notable finding was the trend of annual crop yield (rice yield +wheat yield), where highest was obtained in WS+SS instead of CF, SS or WS treatment. These results reveal that resource quality of organic inputs played important role in regulating the crop yields, which in turn will help in designing the management strategies for sustainable food production in tropical dryland agroecosystem.

Key words : Agroecosystem, crop yield, dryland, organic inputs, resource quality.

Introduction

To fulfil the food requirement of ever increasing population, global agriculture is facing tremendous pressure. Although, maximizing crop yield is the major objective of all agricultural management strategies yet long term sustainability of crop land has now become a global challenge. N being the most critical nutrient for plant growth, chemical fertilizers has generally been used extensively to enhance N availability in soil. However, it has been reported that in 24%-39% of rice and wheat growing areas of the world, the yield has not improved rather has stagnated or in some cases it has started declining (Ray *et al.*, 2012). In addition to this, it has also been reported that less than half of the N added in form of chemical fertilizer is utilized by the crops and rest is lost in the environment causing threats to its various components (Lassaletta *et al.*, 2014). Besides this, the low nitrogen use efficiency and adverse environmental impacts caused by N fertilization increasingly threaten the sustainability of agroecosystems (Duan *et al.*, 2014). As a result, nowadays the focus of research has shifted from high input and maximum yields to low input and high efficiency sustainable agriculture.

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In India, 66% of total arable land is rainfed, characterized by low productivity due to moisture and nutrient limitations. The input of exogenous organic amendments rather than the chemical fertilizers holds promise to ameliorate soil fertility in general and particularly in tropical dryland agroecosystems (Palm *et al.*, 2001). The quantity of organic inputs rather than its resource quality is generally emphasized, however, the resource quality of soil organic inputs exert more influence in regulating the soil nutrients availability, which in turn, governs the productivity of agroecosystems (Roy *et al.*, 2010). Resource quality of organic inputs are generally described on the basis of chemical composition especially C: N ratio and also on the pattern of decomposition of the inputs. The organic inputs can be broadly divided into two major groups (i) Low quality organic inputs and (ii) high quality organic inputs. Low quality organic inputs are characterized by high C: N ratio (>30), releases nutrient slowly or immobilizes nutrients during the early stage of decomposition. Crop residues, mulches, etc are examples of low quality inputs. High quality organic inputs have lower C : N ratios (<30), releases nutrients rapidly after application and examples are green manure and animal manures etc. (Palm *et al*., 2001 and Mohanty *et al*., 2013). High quality and low quality resource inputs may be mixed together in appropriate combination to synchronize nutrient release with crop demand. To increase the crop yield of these vast drylands, there is urgent need to better understand the ecological aspects of soil management in terms of quantity and quality of application of organic inputs that can conserve the soil moisture and sustain long term crop productivity.

The present study was undertaken with the hypothesis that the management of resource quality of exogenous organic inputs could regulate the crop yield of tropical dryland agroecosystem. This study was conducted with the objective of evaluating the effect of incorporating exogenous high resource quality organic input in the form of *Sesbania* shoot, low resource quality organic input in the form of wheat straw, mixed quality organic input in form of combined application of *Sesbania* and wheat straw and inorganic fertilizer on crop yield in rice-wheat summer fallow crop sequence in tropical dryland agroecosystem.

Materials and Methods

Study site

The experiments were conducted in the cultivated area of the Botanical Garden of the Department of Botany, Banaras Hindu University at Varanasi (25°18' N lat. and 83°1' E long., 76 m above the mean sea level). This region has a dry tropical climate, characterized by strong seasonal variations in temperature and precipitation, including a warm rainy season (July–September), a cool winter (November–February), and a hot summer (April–June). The average annual rainfall is 1100 mm, of which approximately 80% is received during the rainy season. High temperature (24–35°C) and relative humidity (70–90%) prevail during the rainy season. In the winter season the temperature range is 10-25°C. The summer is dry and hot with a temperature range of 35 to 45°C during the day. Soil of the site belongs to the order Inceptisol, pale brown in colour and sandy loam in texture with neutral pH.

Experimental design

The experimental fields have been cultivated for decades, with intermittent fallows. Since June 2002 the present experimental set up has been maintained continuously till date. The present study was undertaken for two annual cycles *i.e.* 2010-2011 and 2011-2012. The experimental plots were laid down in a randomized block design using three replicates per treatment. The size of experimental plots was 3m × 3m and was separated by 1 m strip. The experiment was designed to vary the quality of exogenous soil inputs carrying equivalent amount of added N (80 kg N ha^{-1}). The following five treatments were established: (i) high quality organic input in form of *Sesbania aculeata* shoots having C:N::16 (ii) low quality input in the form of wheat straw having C:N::82 (iii) mixed quality input in the form of *S. aculeata* shoot + wheat straw having C:N::47 (iv) chemical fertilizer (containing N:P: K::80:40:30 Kg ha^{-1} in the form of urea, single super phosphate and muriate of potash, respectively) (v) control *i.e.* cropping without addition of any exogenous input. The crop sequence was rice (O*ryza sativa* var NDR-97) as rainy season crop (July-October) followed by wheat crop (*Triticum aestivum* var Malviya 533) as winter season crop (November-March) and then the field were left fallow during summer (April-June). Both crops were directly seeded in the soil and receive natural rainfall only *i.e.* without any irrigation. The exogenous inputs were applied only once in a year before the sowing of rice crop whereas no exogenous inputs were applied for the wheat crop. *S. aculeata* was grown during summer in separate plots and were incorporated directly into the soil after chopping the upper parts of shoot into approximately 2 to 3 cm pieces. Wheat straw was used as recycled crop residue, obtained after harvesting the wheat crop. Air dried wheat straw was cut into approximately 2 to 3 cm pieces applied to the soil. Wheat straw and *S. aculeata* shoots (corrected for moisture content) were incorporated singly or mixed as per treatment into the soil at 5 to 10 cm depth by manual hoeing, 2 days before the sowing of rice crop. Fertilizer was surface applied on the day of sowing.

Crop yield estimation

In each replicate plot of all the treatments, at the end of second year experiment, the aboveground plant parts of both the rice and wheat crop were harvested at the grain ripening stage and the crop yield *i.e.* rice grain with husk and wheat seeds was represented on the dry weight basis.

Results and Discussion

In the present study, the yield of rice was higher compared to wheat across all the treatments (Fig.1). Crop yield in both the crops increased in response to the application of exogenous inputs relative to control. Rice yield across all the treatments ranged from 1710 Kg ha^{-1} -783 Kg ha^{-1} (fig. 1). Maximum rice yield (+118% increase

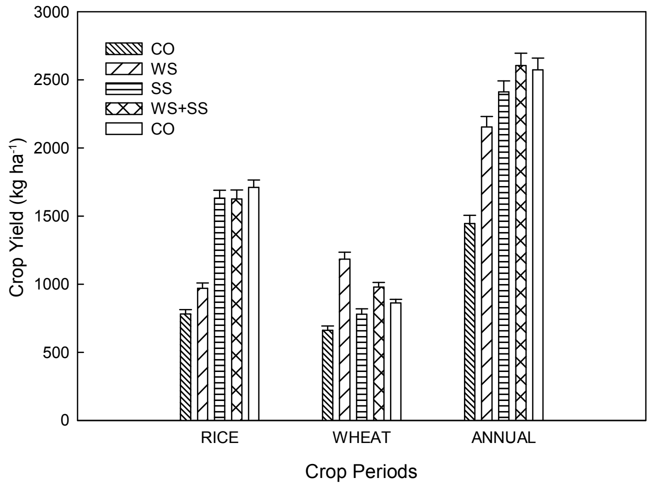

Fig. 1 : Variation in rice, wheat and annual crop yield (Kg ha^{-1}) in response to application of soil amendments with varying resource quality at the end of second annual cycle.

Values are mean ± S.E. Codes: CO: control, WS: wheat straw, SS: *Sesbania*, WS+SS: wheat straw + *Sesbania*, CF: fertilizer.

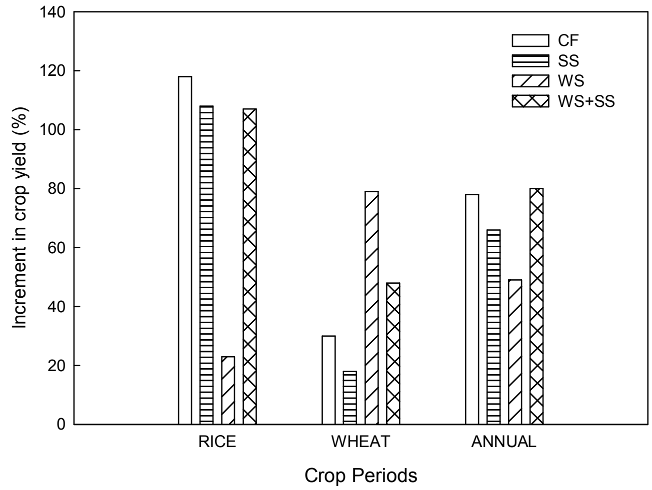

Fig. 2 : Increment in rice, wheat and annual crop yield (% increase over control) in response to application of various soil amendments.

Codes: CO: control, WS: wheat straw, SS: *Sesbania*, WS+SS: wheat straw + *Sesbania*, CF: fertilizer.

over control) was observed in chemical fertilizer followed in decreasing order by *Sesbania* (+108%), wheat straw + *Sesbania* (+107%) and wheat straw (+23%). However, during succeeding wheat crop, the pattern of crop yield was different from that of the rice yield, with highest crop yield in wheat straw treatment. Wheat yield across all the treatments ranged from 1184 Kg ha^{-1}-661 Kg ha^{-1} (fig. 1). During wheat period, the maximum increment (+79%) was found in wheat straw treatment followed in decreasing order by wheat straw + *Sesbania* (+55%), chemical fertilizer (+30%) and *Sesbania* (+18%). Across all the treatments, annual yield ranged from 2606 Kg ha^{-1} -1444 Kg ha^{-1} and the pattern of yield found in various treatments was: wheat straw + *Sesbania* > chemical fertilizer > *Sesbania* > wheat straw and lowest in control (fig. 1).

The rice yield observed in this study was within the range as reported by other workers for this region *i.e.*, 600-1800 Kg ha^{-1}, 800-1200 Kg ha^{-1} and 1039-1835 Kg ha^{-1} as reported by Ghoshal and Singh (1995a), Kushwaha and Singh (2005) and Singh *et al*. (2007a), respectively. However, the wheat yield in the present study was lower than the range reported by others, *i.e*. 2850-3796 Kg ha^{-1} (Hidayatullah *et al*., 2013) and 1209-3374 Kg ha^{-1} (Pandiaraj *et al*., 2015).

In the present study, application of chemical fertilizer resulted early availability of nutrients which was utilized by rice crop and reflected in terms of highest rice yield (Singh *et al*., 2010). However, during subsequent wheat period, nutrients availability was probably reduced either due to their utilization by preceding rice crop or leaching out from the soil resulting in lower wheat yield.

Sesbania shoots, a high quality resource used in this study, decomposed rapidly owing to its low C: N ratio. *Sesbania* shoot decomposition is reported to completed within 120 days (Singh *et al*., 2007b), which almost coincide with the rice crop period and probably translated in the higher crop yield. Nevertheless the limited availability of nutrients in the later phase of annual cycle (wheat period) might be the reason for lower crop yield in this treatment as the nutrients supplied through *Sesbania* treatments during rice period were used completely or were lost from the system subsequently. Higher crop yield for rice crop, and no residual effect of nutrients availability on the second crop yield owing to the application of *Sesbania* is also reported by Singh *et al.* (2004) and Aulakh *et al.* (2000).

The application of low quality resource *i.e.* wheat straw having high C:N ratio so decomposing slow, could have resulted in the immobilization of nutrients initially, causing their deficiency, thus leading to lower crop yield during the rice period. However, the nutrients immobilized during early phase of annual cycle (rice period) could get remineralized during the later phase of annual cycle hence leading to greater nutrients availability (Singh *et al.*, 2007b) and this could be reason for the highest crop yield during wheat period in the present study. Similar findings were also reported by Gangwar *et al*. (2006), Pan *et al*. (2009) and Zhang *et al*. (2015) in rice-wheat cropping systems.

The mixed quality organic input in from of *Sesbania* + wheat straw might have modulated soil nutrient availability at higher concentrations throughout the annual cycle, resulted in relatively higher rice yield, wheat yield and consequently highest annual yield (rice yield + wheat yield). Similar results are also reported by Singh *et al.* (2007a) in the rice barley dryland agroecosystem. In the literature, contrasting reports are also available on the effect of organic resources with varying resource quality on the crop yield. Singh *et al*. (2014) reported the application of *Sesbania* along with farmyard manure enhanced the rice and wheat yields in rice wheat cropping system in Indogangetic plains of India and emphasize the need for 100% use of organic sources instead of being dependent on only fertilizer. However, Singh *et al*. (2004) reported increased in the rice yield due to combined application of farmyard manure and green manure compared to the green manure or wheat straw alone or in combination with urea in the rice-wheat cropping system, yet the residual effects of these organic inputs on wheat yields were not noticed. No significant increase in rice yield was observed by Aulakh *et al*. (2001) due to application of wheat residue singly or in combination with urea N in tropical semiarid rice wheat system.

Conclusion

In the present study, it was observed in rice-wheat cropping sequence of tropical dryland agroecosystem that application of *Sesbania* (high quality plant input) was more effective in case of rice, whereas application of wheat straw (low quality input) was more beneficial to succeeding wheat crop. Through the annual cycle, higher crop yield was achieved in mixed quality input (*Sesbania* + wheat straw) instead of single application of *Sesbania*, wheat straw or chemical fertilizer in spite of addition of equivalent amount of N. It is concluded from this study that resource quality of organic inputs play important role in regulating crop yield. Appropriate combination of organic inputs of varying resource quality may help in agroecosystem.

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