International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(2): 1102-1106

Received: 06-01-2020
Accepted: 09-02-2020

Effect of rice residue management and crop diversification on growth and yield of rice

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DOI: https://doi.org/10.22271/chemi.2020.v8.i2q.8914

Abstract
RWCS is the most dominant and extensive cropping system across South Asian Indo-Gangetic Plains. It has the deleterious effects on the soil physical properties and leads to ample amount of residue generation. Residue managements is the biggest question that arises thereby to overcome these problems and to maintain the sustainability an experiments was held during the *Kharif* season of 2017 at N. E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, US Nagar, Uttarakhand situated at 29◦N, 79◦29E and at an altitude of 243.86 above mean sea level, to evaluate the effect of crop diversification and residue management techniques through organics on rice growth and productivity. It has been observed that diversification of RWCS as rice-yellow sarson-groundnut and rice-vegetable pea-maize along with 30% residue management through organics viz., vermicompost @ 2 t ha^{-1}, FYM @ 5 t ha^{-1} and biogas slurry @ 2 t ha^{-1} can be advocated for enhancing the growth and productivity of rice and the 30% residue management through organics viz., vermicompost @ 2 t ha^{-1} and rice-yellow sarson-groundnut perform best among them with the grain yield of 7.12 t ha^{-1} and 6.44 t ha-^{1}, respectively.

Keywords: Diversification, Sarson-groundnut and organics

Introduction

Rice-wheat cropping system is the foremost production system covering an area of 13.5 million hectares across South Asian Indo-Gangetic Plains (IGP) (Ladha *et al*., 2003) [12] and feeds about one-fifth of the world population. In Asian nations, this framework represented around 32% and 42% region of the complete rice and wheat, individually (Memon *et al*., 2018) [14]. Capital and vitality concentrated traditional administration rehearses for rice and wheat development puts this life-supporting creation framework on a ventilator. Supportability of rice and wheat creation is under risk because of monotonous husbandry in a similar territory of field. Henceforth, the efficiency upgrade of RWCS is the prime essential to take care of the quickly expanding population of India, which is anticipated to increment to 1.35 billion by 2025 (UNEP, 2008) [25].

Crop diversification through the incorporation of legume in cereal have supplementary advantages well beyond the addition of nitrogen through biological nitrogen fixation including improved soil fertility and mitigate the impact nutrient mining and along with breaking the monotony of rice-wheat production system (Bezner Kerr *et al*., 2007; Wani *et al*., 1995) [2, 27]. Legumes incorporation in a framework expands grain yield of resulting crop, and subsequently improves the SOC in legume-cereal rotation. An increase in SOC by more than two-folds within 13 years of rice-wheat annual rotation when legumes were integrated into a crop rotation (Rekhi *et al*., 2000) [17].

On-farm burning is the common practice followed by farmers for clean cultivation, adoption of farm mechanics and pest management. According to National Policy for Management of Crop Residues, the crop residue generation is highest in Uttar Pradesh (60 Mt) followed by Punjab (51 Mt) and Maharashtra (46 Mt) with a grand total of 500Mt per year (Bhuwaneshwari *et al*., 2019) [3]. In India according to IPCC over 25% of the total crop residues were burnt on the farm major contribution was 43% of rice, followed by wheat (21%), sugarcane (19%) and oilseed crops (5%). Open agricultural crop residues, burning to release a great number of pollutants to

the atmosphere, which includes aerosols and hydrocarbons (Tripathi *et al.*, 2013) [24]. So, to overcome this residue recycling is the best possible way out.
Residue incorporation also improves aggregate stability (Keller *et al.*, 2007) [10] and porosity, infiltration, water holding capacity and water availability (Jemai *et al.*, 2013) [9]. Residue recycling also influences the availability of macro and micronutrients such as zinc and iron, and it is an important factor in maintaining the cumulative Silicon balance in rice (Dobermann and Fairhurst, 2000) [7]. However, 100% of residues incorporation of cereals is very difficult to use as the C: N ratio of the residue is very high. Hence, there is an urgent need to develop a technology to efficiently use the crop residue. Therefore, the organics like well-decomposed farmyard manure, vermicompost which have the lower C: N ratio were mixed with crop residue to lower down the C: N ratio to overcome temporary immobilization of plant nutrients (Davari *et al.*, 2012) [6]. It is observed that the organic manure incorporation with crop straw into soil enhances the soil properties like better aggregation, improves nutrient availabilty and increases crop yield (Eneji *et al.*, 2001; Singh *et al.*, 2001) [8, 21]. Crop residue recycling is an essential component in achieving sustainability; improvement in soil condition not necessarily always flows to yields (Singh *et al.*, 2005) [20].

Material and Method

Experimental Detail

Experiment was conducted in Split Plot Design with three cropping systems viz. rice-wheat, rice-vegetable pea-maize and rice-yellow Sarson-groundnut in main plot and five residue management techniques viz. farmer's practice, 30% residue recycling, 30% residue recycling + FYM @ 5 t ha-^{1}, 30% residue recycling + Biogas slurry @ 2 t ha-^{1} and 30% residue recycling + Vermicompost @ 2 t ha-^{1} replicated thrice. The residue was incorporated in the field in all the treatments except control (C_1T_1, $C_2T_1$and C_3T_1). Based on crop rotation, 30% crop residue of the preceding crop was incorporated i.e. 30% of the total residue produced as depicted below. The residue was incorporated by ploughing followed by harrowing.

Table 1: Amount and date of residue incorporated

Crop	Residue produced (q/ha)	Amount applied (q/ha)	Date of residue application
Wheat	60	18	15/04/2017
Groundnut	40.5	12.15	28/06/2017
Maize	116.7	35.01	18/06/2017

The organics used in the experiment were FYM, vermicompost and biogas slurry. FYM @ 5t/ha, vermicompost @ 2t/ha and biogas slurry @ 2t/ha; was applied just before puddling as per the treatment so that it gets mixed in the soil. The samples of organics were taken and through laboratory analysis, the N, P and K percentage present in organics was calculated.

Table 2: Percentage of nutrient present in organics applied

Organics	C%	N%	P%	K%	C: N
FYM	16.2	0.59	0.26	0.50	27
Vermicompost	24.5	1.21	0.78	0.90	20
Biogas slurry	15.96	1.05	0.45	0.55	15

The treatments were replicated with size 3×8.3m^2. Twenty-two days old rice seedlings of "HKR-47" were transplanted in July. In all the treatments nitrogen, phosphorus, potassium and zinc were supplied through urea, diammonium phosphate, muriate of potash and zinc sulphate, respectively. The nitrogen is applied in three split doses. Entire P and K and 50kg N were applied as basal. However, the 1st top dressing was done at 28 DAT and 2nd top dressing was done at 49 DAT through Green seeker. The foliar zinc was sprayed 10 and 20 days after transplanting of rice. Harvesting was done manually when more than 90 per cent of grains in the panicle were fully ripe and free from greenish tint. The observation for growth, development was recorded from the sampling area under field condition.

Growth Attributes

Growth attributes were recorded at maturity is given in table 1. Shoot height (cm) was measured with a meter scale from the base of the plants to the tip of the panicle. Number of shoots per meter square was recorded. For determining the dry matter accumulation, crop samples were clipped closed to the ground and collected in polythene bags. The plants were then washed with water and collected in paper bags thereafter, the plants were dried in drier at 70 ± 2◦C temperatures for 48-72 hours up to constant weight. After drying, their weights were recorded. The weight thereafter converted into gram dry matter per square metre (gm^{-2}).

Yield

Biomass weight of sun-dried crop from net plot was considered as biological yield which was further converted into tons per hectare (t ha^{-1}). Yield attributes were given in table 2. Grain yield is obtained after threshing and cleaning. The grain yield was converted to t ha^{-1} after adjusting grain moisture at 10%. Straw yield per plot was obtained by subtracting the grain yield from biological yield produced per plot and converted to t ha^{-1} after adjusting straw moisture at 14%. The harvest index is determined by dividing the total grain yield and the total biological yield. Yield parameters are given in table 2.

Result and Discussion

Growth Attributes

The growth attributes were significantly affected by diversification and the residue management. Shoot height, number of shoots m^{-2} and dry matter accumulation (g m^{-2}) were significantly higher under C_3 (rice-yellow sarson-groundnut cropping system) over under C_2 (rice-vegetable pea-maize cropping system) and C_1 (rice-wheat cropping system). Lowest shoot height was observed under C_1. Shoot height in C_3 was 3.97% higher than the C_1. Number of shoots m^{-2} and dry matter accumulation was statistically at par with C_2. The least number of shoots m^{-2}and dry matter accumulation was observed C_1 i.e. 285 and 1393.3g m^{-2}, respectively.
Pulses have the capability to fix the atmospheric nitrogen through biological nitrogen fixation. Inclusion of legumes in the cropping system as it add nitrogen to the soil through biological nitrogen fixation thereby improves soil health and resulted in better growth of the rice such as plant height, dry matter accumulation, number of shoots which is supported by Davari *et al.* (2002) [5] who reported that the N content, microbial population i.e. numbers of bacteria, fungi, and actinomycetes in soil was higher under rice-wheat-maize cropping system (RWMCS) than under (RWCS) rice-wheat cropping system thereby results in maximum shoot height and dry matter production of rice under (RWMCS). Porpavai *et*

al. (2011) [16] at Thanjavur reported that inclusion of legume in rice-based cropping system contributed 0.04% increase in organic carbon thereby provides proper nutrient supply and increased the number of shoots and dry matter accumulation of crop. Sharma and Sharma (2003) [19] reported the enhanced growth of rice crop i.e. shoot height, number of shoots by crop diversification as the available N content in soil decreased by 1.5kg ha^{-1} after two cycles of rice-wheat cropping system but increased by 9.6, 13.8 and 14.1 and 3.5 kg ha^{-1} after two cycles of rice-potato-mungbean, rice-wheat-mungbean, rice-rapeseed-mungbean and rice-clover cropping systems, respectively. As the shoot height, a number of shoots and dry matter accumulation of the crop increases, the photosynthetic area also increases results in higher photosynthesis which leads to a higher yield of the crop. (Sharma and Sharma, 2005) [18] reported that the inclusion of legume i.e. mungbean in the rice-wheat system results in higher productivity and profitability.

Table 3: Growth attributes of rice as influenced by different treatments at different stages of crop growth

Treatments	Shoot height (cm)	Number of shoots m^{-2}	Dry matter accumulation (g m^{-2})
Cropping System			
C_1-Rice-wheat	125.8	285	1393.3
C_2-Rice-vegetable pea-maize	127.4	298	1435.6
C_3-Rice-yellow sarson-groundnut	130.8	307	1505.2
SEm (±)	0.90	4.14	21.34
CD at 5%	3.54	16.3	83.80
A. Residue management techniques			
T_1-Farmer's practice	125.3	273	1400.2
T_2-30% residue recycling	126.3	278	1404.9
T_3-T_2 +FYM	128.0	305	1466.8
T_4-T_2+biogas slurry	130.2	304	1458.8
T_5-T_2+vermicompost	130.1	321	1492.8
SEm (±)	1.32	3.39	18.85
CD at 5%	3.85	9.9	55.03

Among the different residue management techniques T_4 (biogas slurry @ 2 t ha^{-1} + 30% residue recycling) was significantly higher than different treatments but was at par with T_2 (30% residue recycling), T_3 (FYM @ 5 t ha^{-1} + 30% residue recycling) and T_5 (vermicompost @ 2 t ha^{-1} + 30% residue recycling). The percent increase in shoot height in T_4 (biogas slurry @ 2 t ha^{-1} + 30% residue recycling) over T_1 (farmer's practice) was 3.91%. which might be due to the increased mineralization rate of biogas slurry than vermicompost and the FYM supported by the study which revealed that application of biogas slurry and bio-mineralizer increases the rate of residue decomposition (narrow C: N) and the soil microbial population and provide a higher number of shoots. Therefore, residue incorporation + 25 kg additional nitrogen + biogas slurry + bio-mineralizer are beneficial for residue retention Vijayaprabhakar *et al*. (2017) [26]. Nandan *et al*., (2018) [15] noticed that crop residue retention significantly improve shoot height (3.9-4.3%) in rice. The maximum number of shoots $m^{-2}$was recorded in T_5 (vermicompost @ 2 t ha^{-1} + 30% residue recycling) was significantly higher than all the treatments. The percent increase in number of shoots m^{-2} 17.58% over T_1 (farmer's practice). Dry matter accumulation m^{-2} was maximum in T_5 (vermicompost @ 2 t ha^{-1} + 30% residue recycling) and was statistically at par with T_3 (FYM @ 5 t ha^{-1} + 30% residue recycling) and T_4 (biogas slurry @ 2 t ha^{-1} + 30% residue recycling). The increase in dry matter accumulation m^{-2} was 6.61% over C_1 (rice-wheat cropping system), respectively. The C: N ratio of the crop residue is very high and its incorporation into the field leads to temporary immobilization but the incorporation of vermicompost, biogas slurry and FYM lowers the C:N ratio and results in faster decomposition of the residue which improves the nutrient status of the soil and these organics also add nutrient to the soil and improves the soil properties. Therefore, results in better availability of nutrient to the crop. Similar results were reported by Bilkis *et al.* (2015) [4] that the maximum plant height, number of shoots, dry matter accumulation and other growth attributing characters was observed in tricompost + chemical fertilizer but was statistically at par with vermicompost + chemical fertilizer followed by cow dung slurry + chemical fertilizer supported by Srivastava *et al.* (2014) [22]. They observed that the integration of organics and inorganics source of nutrients regulates the balanced supply of nutrients in adequate quantity over prolonged period of crop growth and also reported that continuous supply of balanced quantity nutrients throughout the growth stages enabled the plant to assimilate sufficient amount of photosynthetic product and thus increased the dry matter accumulation. Similar results were found by Sudhakar *et al*. (2006) [23] for rice crop.

Yield

Diversification and the residue management techniques have the significant affect on the yield components. The maximum grain yield was observed under C_3but was statistically at par with C_2. The percent increase in the grain yield in C_3 over C_1 is 11.23%. The straw yield and the biological yield were maximum in C_3 i.e. 8.30 and 14.74 t/ha, respectively followed by C_2 and C_1. There were no significant difference in terms of harvest index and grain: straw ratio. Diversification of rice wheat cropping system enhances improves the growth of the plant which results in better productivity.

Table 4: Yield of rice as influenced by different cropping system and residue management techniques

Treatments	Yield (t ha^{-1})			Harvest Index	Grain: Straw
	Grain	Straw	Biological		
Cropping System					
C_1-Rice-wheat	5.79	7.22	13.01	44.50	0.80
C_2- Rice-vegetable pea-maize	6.21	7.85	14.06	43.12	0.79
C_3-Rice-yellow sarson-groundnut	6.44	8.30	14.74	44.61	0.77
SEm (±)	0.19	0.11	0.12	0.59	0.02
CD at 5%	0.36	0.44	0.48	NS	NS
Residue management techniques					
T_1- Farmer's practice	5.42	7.14	12.58	43.28	0.76
T_2-30% residue recycling	5.35	7.08	12.43	43.11	0.76
T_3-T_2 +FYM	6.45	8.05	14.50	44.46	0.80
T_4-T_2+biogas slurry	6.38	7.76	14.13	45.14	0.82
T_5-T_2+vermicompost	7.12	8.93	16.05	44.40	0.80
SEm (±)	0.11	0.16	0.22	0.53	0.02
CD at 5%	0.33	0.45	0.63	NS	NS

Within the different residue management techniques, grain yield was significantly higher in T_5 than all other treatments. The lowest grain yield was observed in T_2 (30% residue recycling) which was at par with T_1 (farmer's practice). The increase in grain yield in T_5 over T_1 was 31.36%. The maximum straw and biological yield was observed in T_5which is significantly higher than other treatments. The percent increase in straw and biological yield over control (T_1) was 25.07 and 27.9%, respectively. The effect of residue management technique was non-significant in terms of harvest index and grain: straw ratio. The organic applied treatments results in the better growth of the crop due to long term availability of nutrients due to their slow release pattern of organics. Among organics, vermicompost perform better due to its slowest release pattern and higher nutrient percentage. Similar results were shown by Davari and Sharma (2012) [6]. They reported that among different treatments i.e. FYM @ 60 kg N ha^{-1}; FYM + rice residue @ 6 t ha^{-1} (RR); FYM + RR + bio fertilisers (B); vermicompost @ 60 kg N ha^{-1} (VC); VC + RR and VC + RR + B , the application of vermicompost + crop residue + bio fertilisers showed highest grain. While comparing the different treatment availability of NPK was significantly higher in vermicompost treated plots than FYM reported by Barik *et al.* (2006) [1] but among different organics, biogas slurry was least effective due to its faster N release pattern, which enabled maximum nitrogen availability only up to 30 days coincides with tillering stage similar result was reported by Kumar *et al.* (2018) [15]. Lungmuana *et al.* (2016) [13] reported that the grain and straw yield of rice was significantly higher under the treatment combination of chemical fertilizer + vermicompost over control and followed by chemical fertilizer + FYM.

Conclusion

Diversification of rice-wheat system as rice-yellow sarson-groundnut and rice-vegetable pea-maize results in better growth of the crop which thereby increases the yield. Residue management's techniques where the organics are used to increase the rate of decomposition of the residue by lowering the C: N ratio also results in higher yield that other. Among these residue management techniques the treatment where 30% residue management through vermicompost @ 2 t ha^{-1} was applied performed best in terms of both growth and yield.

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