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Research Paper

Integrated nutrient management in pearl millet (*Pennisetum glaucum*)–wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was conducted during 2014–15 and 2015–16 at Swami Keshwanand Rajasthan Agriculture University, Bikaner, Rajasthan, to evaluate the effect of integrated nutrient management on yield of wheat (*Triticum aestivum* L.) and succeeding pearl millet [*Pennisetum glaucum* (L.) R. Br.] crop. The experiment was laid out in a split-plot design with 3 replications comprising different treatment combinations. Incorporation of 75% recommended dose of fertilizer (RDF) + 5 t farmyard manure (FYM)/ha + *Azotobacter* + phosphate-solubilizing bacteria (PSB) in wheat, significantly increased yield attributes and yield (4.12 t/ha) of wheat and uptake of nutrients (N, P, K) in both grain and straw of wheat, but remained at par with 100% RDF + 5 t FYM/ha + *Azotobacter* + PSB. The yield of succeeding pearl millet was significantly higher under all INM (integrated nutrient management) treatments applied in preceding wheat over the control and 100% RDF.

Key words: Correlation, Cropping system, Nutrient uptake, Pearl millet, Regression, Wheat

Many intensive cereal-based cropping systems are under practice in the country according to agro-climatic regions. In Indo-gangetic plains of India, pearl millet-wheat (*Triticum aestivum* L.) cropping system is the second most prominent and popular double-copping system after rice–wheat of the country and spreads over arid eco-regions. It is the most dominating cropping system of Rajasthan (Kumar *et al.,* 2019). Wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] is the most important staple food crop of the world and emerged as the backbone of India's food security (Prasad, 2006). Wheat productivity is highly variable within different agro-ecologies of India, due to variable climatic conditions, genotypes, seeding time and practices; and other management practices (Kantwa *et al.,* 2015). It is also evident that biofertilizers like *Azotobacter* and phosphate-solubilizing bacteria (PSB) alone or in combination have great prospect for increasing productivity of wheat.

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Systematic use of diverse sources for nutrients, viz. bio fertilizers, organic manures and inorganic fertilizers has been also known to improve benefit: cost ratio of fertilization, agronomic efficiency and partial factor productivity in wheat-based cropping system (Bhattacharya *et al.*, 2010). Long-term studies being carried out at several locations in India indicated that, application of all the required nutrients through chemical fertilizers have deteriorating effect on soil health leading to unsustainable yields (Eid *et al.*, 2006). Although organic manure alone cannot produces the sufficient food for present population. Under these circumstances integration of chemical, organic and biofertilizer sources and their management have shown promising results not only in sustaining the productivity but have also proved effective in maintaining soil health and enhanced nutrient-use efficiency (Chesti *et al.*, 2013; Walia and Patidar, 2021).

Pearl millet [*Pennisetum glaucum* (L.). Br Emend stuntz.] being grown in rainfed as well as in irrigated conditions in rainy (*kharif*) season crop in the state as staple food crop. Though, Rajasthan ranks first in area and production both, its cultivation is mainly confined to the arid (62% of total area) and semi-arid (12.60% of total area) regions. The pearl millet is highly affected by previous cropping system, applied nutrients, amounts and their sources. Beneficial residual effects of organic manure and for fertilizer particularly of phosphorus applied into wheat may increase yield of succeeding crop (Bhattacharya *et al.,* 2010). Thus, in intensive cropping system, wheat-pearl millet cropping system became very popular in north-western Rajasthan. Keeping all these points in view, a study was carried out to study the effect of integrated nutrient management on wheat and direct and residual effect of nutrients on succeeding pearl millet.

MATERIALS AND METHODS

A field experiment was conducted during the winter (*rabi*) and rainy (*kharif*) seasons of 2014–15 and 2015–16 at the Swami Keshwanand Rajasthan Agricultural University, Bikaner, (28.01° N, 73.22° E, 234.7 m above mean sea-level), Rajasthan. The average annual rainfall of the tract is about 260 mm which is mostly received during the rainy season. Soils are loamy sand with 0.109% organic carbon (Walkley-Black C), alkaline $KMNO_4$-oxidizable N 120.4 kg/ha, 0.5 M $NaHCO_3$-extractable P 18.68 kg/ha and 1 N NH_4OAc-extractable K 214.6 kg/ha. The experiment was started with the sowing of winter season crop first and then residual study was taken on succeeding rainy season pearl millet during both the years. Experiment was laid out in a split-plot design with 3 replications, comprising different treatment combinations, i.e. control, 50, 75 and 100% recommended dose of fertilizer (RDF), 50% RDF + FYM (5 t/ha), 75% RDF + FYM (5 t/ha), 100% RDF + FYM (5 t/ha), 50% RDF + FYM (5 t/ha) + *Azotobacter* + phosphate-solubilizing bacteria (PSB), 75% RDF + FYM (5 t/ha) + *Azotobacter* + PSB and 100% RDF + FYM (5 t/ha) + *Azotobacter* + PSB, applied in wheat as main plots (with gross plot size of 39 m^2/plot) and 3 fertility levels (control, 50% and 75% RDF) as subplot (gross plot size 12 m^2/plot) in succeeding pearl millet comprising a total of 30 treatment combinations. The recommended dose of fertilizer for wheat was 120 kg/ha N, 40 kg/ha P_2O_5 and 20 kg/ha K_2O and for pearl millet 60 kg/ha N, 40 kg/ha P_2O_5. Half dose of nitrogen and full dose of phosphorus and potassium were applied basal at the time of sowing. Remaining nitrogenous fertilizer was applied in 2 equal splits – at the first irrigation and the second irrigation. The FYM was applied before sowing of winter crop on the nitrogen-equivalent basis and requirement of crop in respective treatments. Seeds of wheat were treated with *Azotobacter* and PSB in respective treatments at the time of sowing. The wheat 'Raj 3077' was sown at 20-cm-row spacing on 20th and 26th November during 2014 and 2015, respectively and harvested on 1st and 8th April 2015 and 2016. After harvesting of wheat, pearl millet was taken as a test crop to study the residual effect of INM applied in wheat. Variety 'HHB 67 Improved' was used for sowing of pearl millet @ 5 kg/ha at 30 cm spacing between rows by *kera* method on 16th and 9th July in 2015 and 2016, respectively, and harvested on 3rd October 2015 and 26th September 2016. Different yield attributes of wheat were studied. Numbers of tiller-bearing productive spikes were counted in 5 randomly selected 1 m row length in each plot at physiological maturity of the crop. These were averaged to record and express effective tillers/m row length. Number of grains were counted from the randomly selected 10 spikes under each plot and averaged to express as number of grains/spike. A seed sample was taken from the produce of each of the net plot harvested and 1,000 seeds were counted and weighed to record as test weight in gram. The representative samples grains as well as straw of wheat crop collected at harvesting were dried in hot air oven at 60°C for 48 hours. The oven-dried samples were ground to pass through 40 mesh-sieve. Nitrogen was estimated by Kjeldahl's method (Snell and Snell, 1949), P concentration by vanado-molybdo-phosphoric yellow colour method (Jackson, 1967) and K concentration by flame photometer method (Jackson, 1967). The uptake of nutrients was computed by multiplying the concentrations with dry weight of respective plant parts. The grain, straw and biological yields of each net plot (inclusive of tagged plants) were recorded in kg/plot after cleaning the threshed produce and converted into t/ha. In residual study, yield attributes, viz. effective tillers/m row length, grains weight/ear and ear length, and yields (grain, stover and biological) of pearl millet were studied. Benefit: cost ratio was calculated. The data years were analysed statistically using the F-test, as per the standard procedure. Correlation and regression coefficients between seed/grain yield and yield attributes were computed by using the methods described by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Effect of integrated nutrient management on wheat

Among the different nutrient sources, application of 75% RDF + FYM 5 t /ha + *Azotobacter* + PSB resulted in significantly higher yield attributes, i.e. effective tillers/m row length (no.), spike length (cm) and grains/spike, of wheat and found at par with 100% RDF + 5 t FYM /ha + *Azotobacter* + PSB (Table 1). Thus there was saving of 25% of recommended dose of fertilizers. This may be attributed to higher availability of nutrients in FYM and biofertilizer treatments that increased the availability of both the native and applied nutrients and better source and sink relationship that contributed to better dry-matter production of crops, leading to the production of favourable yield components (Verma *et al.,* 2016).The enhanced yield components might also be owing to the increased growth attributes, leading to higher photosynthetic rate and accumulation of more assimilates which in turn increased the sink size. As a result, almost all yield attributes of crop resulted in significant improvement because of integration of organic sources with inorganic nutrient sources (Verma *et al.,* 2016). Walia and Patidar (2021) also observed the highest dry matter accumulation with integrated treatment.

Wheat grain, straw and biological yields were significantly higher with the application of different nutrient sources than the control (Table 1). Incorporation of 75% RDF + 5 t FYM /ha + *Azotobacter* + PSB resulted in significantly higher grain yield (4.06 t/ha) of wheat (Table 1) than other treatments, but it was at par with 100% RDF + 5 t FYM/ha + *Azotobacter* + PSB (4.15 t/ha). Our results confirm the findings of Bangre *et al.,* (2020), who reported that combined application of organic and inorganic fertilizers significantly influenced the yield of wheat. The integrated use of organic manure (FYM), inorganic source of nutrients and biofertilizers might have supplied readily available nutrients to wheat which resulted in greater assimilation, production and partitioning of dry-matter yield, which finally enhanced the yield. Kidane (2014) and Kumar *et al.,* (2019) also reported similar results. Choudhary (2017) reported that, the highest grain yield of wheat realized with application of 100 % RDF + *Azotobacter* + PSB of plant nutrition could be due to its profound influence on vegetative and reproductive growth of the crop. In addition, the presence of plant-growth-promoting substances such as plant growth hormones and humic acids in FYM has also been suggested as a possible factor contributed to enhanced yield (Taleshi *et al*., 2011). Kandil *et al.,* (2011) reported that, inoculation with *Azotobacter* in wheat resulted in higher plant growth, yield attributes and yield than non-inoculated cultivars. Higher yield attributes with 75% RDF + 5 t FYM /ha + *Azotobacter* + PSB are thus responsible for increased yields which could also be explained by positive correlation between yield attributes and yield of wheat (Figs. 1, 2).

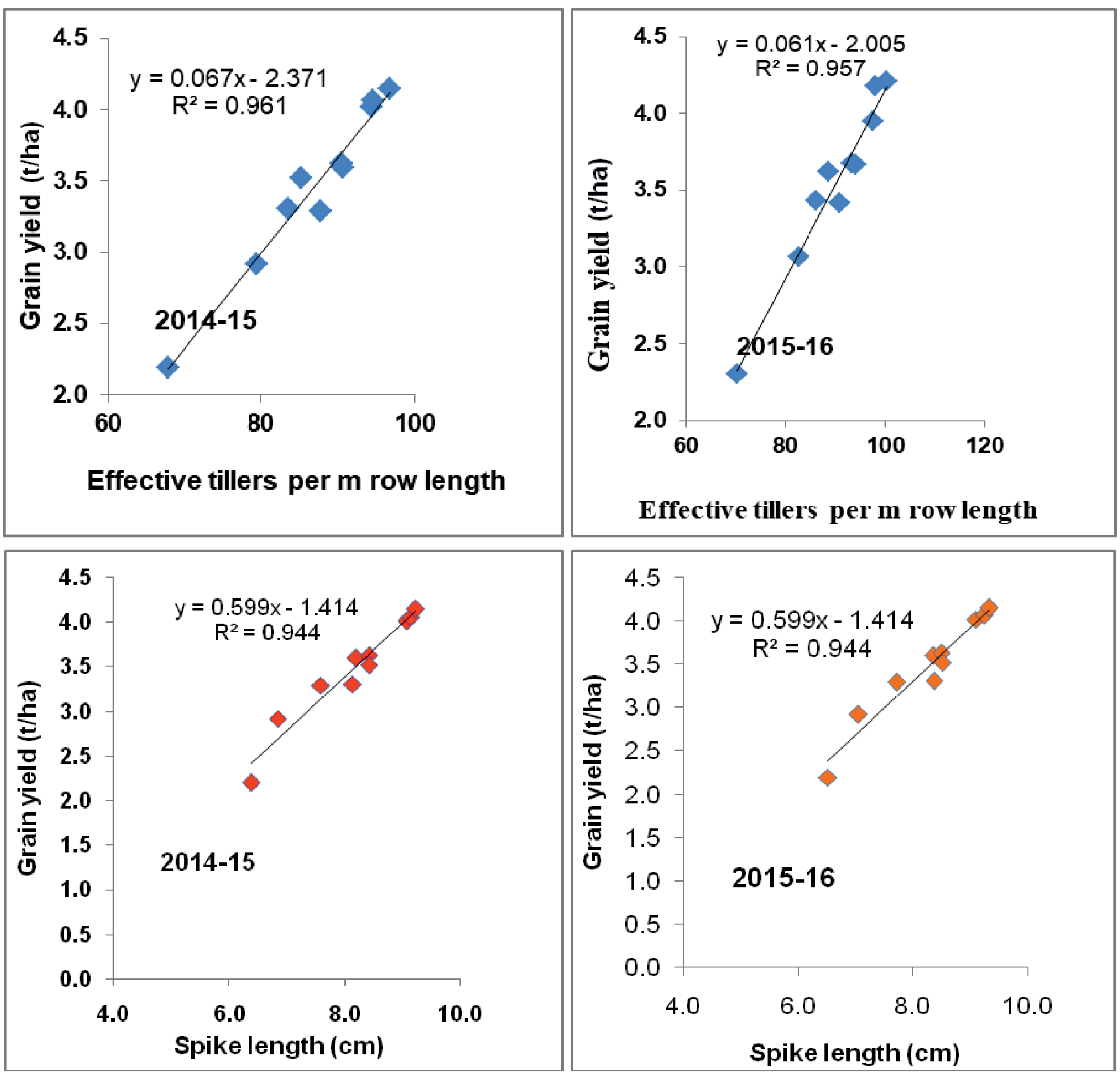

Fig. 1. Correlation of wheat grain yield with yield attributes, viz. effective tillers and spike length

Table 1. Effect of integrated nutrient-management (INM) on yield attributes, yield and nutrient uptake in wheat (pooled mean of 2 years)

Treatments	Yield attributes			Yield (t/ha)			N uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)		
	Effective tillers/m	Spike length (cm)	Grains/ spike	Grain yield	Straw yield	Biological yield	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
INM in wheat															
Control	69.08	6.46	24.78	2.25	3.64	5.89	33.57	20.61	54.18	9.35	7.41	16.76	10.62	42.52	53.14
50% RDF	81.03	6.95	25.74	2.99	4.70	7.69	46.21	29.06	75.27	13.47	9.79	23.26	14.59	55.06	69.65
75% RDF	89.32	7.65	26.21	3.35	5.16	8.51	53.87	33.60	87.47	16.00	11.02	27.03	16.52	61.10	77.62
100% RDF	92.42	8.27	26.56	3.63	5.49	9.12	61.72	37.89	99.61	18.42	12.13	30.55	18.09	65.81	83.90
50% RDF + FYM 5 t/ha	84.85	8.26	28.06	3.37	5.02	8.39	53.54	31.77	85.30	15.82	10.50	26.32	16.60	60.18	76.78
75% RDF + FYM 5 t/ha	91.96	8.46	28.22	3.65	5.55	9.19	61.53	37.74	99.27	18.62	12.29	30.90	18.21	68.29	86.50
100% RDF + FYM 5 t/ha	95.94	9.09	29.79	3.98	5.86	9.84	70.47	43.10	113.57	20.82	13.49	34.31	20.13	73.95	94.09
50% RDF + FYM 5 t/ha + *Azotobacter* + PSB	86.94	8.47	28.63	3.57	5.21	8.78	57.21	33.94	91.16	17.16	11.01	28.17	17.77	64.06	81.83
75% RDF + FYM 5 t/ha + *Azotobacter* + PSB	96.38	9.20	30.21	4.12	5.89	10.01	73.37	43.80	117.17	21.69	13.62	35.31	21.04	75.31	96.35
100% RDF + FYM 5 t/ha + *Azotobacter* + PSB	98.52	9.28	31.18	4.18	6.03	10.20	75.41	45.61	121.02	22.31	14.33	36.65	21.77	77.86	99.62
SEm±	0.93	0.16	0.51	0.10	0.08	0.13	1.74	0.69	1.80	0.54	0.27	0.61	0.77	2.23	2.20
CD (P=0.05)	2.66	0.46	1.46	0.29	0.22	0.37	4.99	1.97	5.16	1.55	0.77	1.76	2.22	6.41	6.31

RDF, recommended dose of fertilizer; FYM, farmyard manure; PSB, phosphate-solubilizing bacteria, 100% RDF for wheat; 120 N: 40 P_2O_5: 20 K_2O

Nutrient uptake by wheat

Among the different nutrient sources, an application of 100% RDF + 5 t FYM + *Azotobacter* + PSB significantly increased the total nitrogen uptake by wheat (Table 1). Application of 75% RDF + 5 t FYM + *Azotobacter* + PSB and 100% RDF + 5 t FYM + *Azotobacter* + PSB increased the total nitrogen uptake by 116.26 and 123.37 and 17.63 and 21.50%; total phosphorus uptake by 110.64% and 118.61% and 15.58% and 19.95%; and the total potassium uptake by 81.31% and 87.47% and 14.84% and 18.74% as compared to the control and 100% RDF respectively. This might be because of improved nutritional environment in the rhizosphere as well as in the plant system, leading to enhanced translocation of N, P and K in plant parts. Hashim *et al.* (2015) reported that, the integrated nutrient treatments might have resulted in sufficient amount of released nutrients by mineralization at a constant level and increased the nutrient uptake because of the better soil environment created owing to cumulative effect of organic sources combined with inorganic source of nutrients, which improved the plant growth and consequently enhanced the yield attributes and yield. Bangre *et al.* (2020) in their findings confirmed that, balanced use of organic and inorganic fertilizers provides higher nutrient content and quality of wheat.

Residual effect of integrated nutrient management on succeeding pearl millet

Application of integrated nutrient-management treatments comprising 75 to 100% RDF and 5 t FYM /ha with or without biofertilizers to the preceding wheat resulted in significantly higher effective tillers/m row length, grain and stover yields of pearl millet over the control and the other treatments during both the years and in pooled mean (Table 2). The significant increase in grain, straw and biological yields owing to the influence of FYM and fertilizers particularly of phosphorus was largely a function of improved growth and the consequent improvement in yield attributes (Singh *et al.,* 2008; Jain and Dahama, 2006). Further, manure increased the efficiency of added chemical fertilizer, particularly of phosphorus in soil and rate of humification. Humic acid in FYM might have enhanced the availability of both native and added nutrients in soil as a result of improved growth, yield attributes and yield of the succeeding crop significantly (Babli and Malik, 2018; Yadav *et al.,* 2003).

Direct effect of fertilizers on pearl millet

Significant increase in grain yield, i.e. 1.43 t/ha (Table 2), of pearl millet with increasing levels of fertilizer (75% RDF) owing to improvement in yield-attributing characters like effective tillers/m row length, ear length and grain

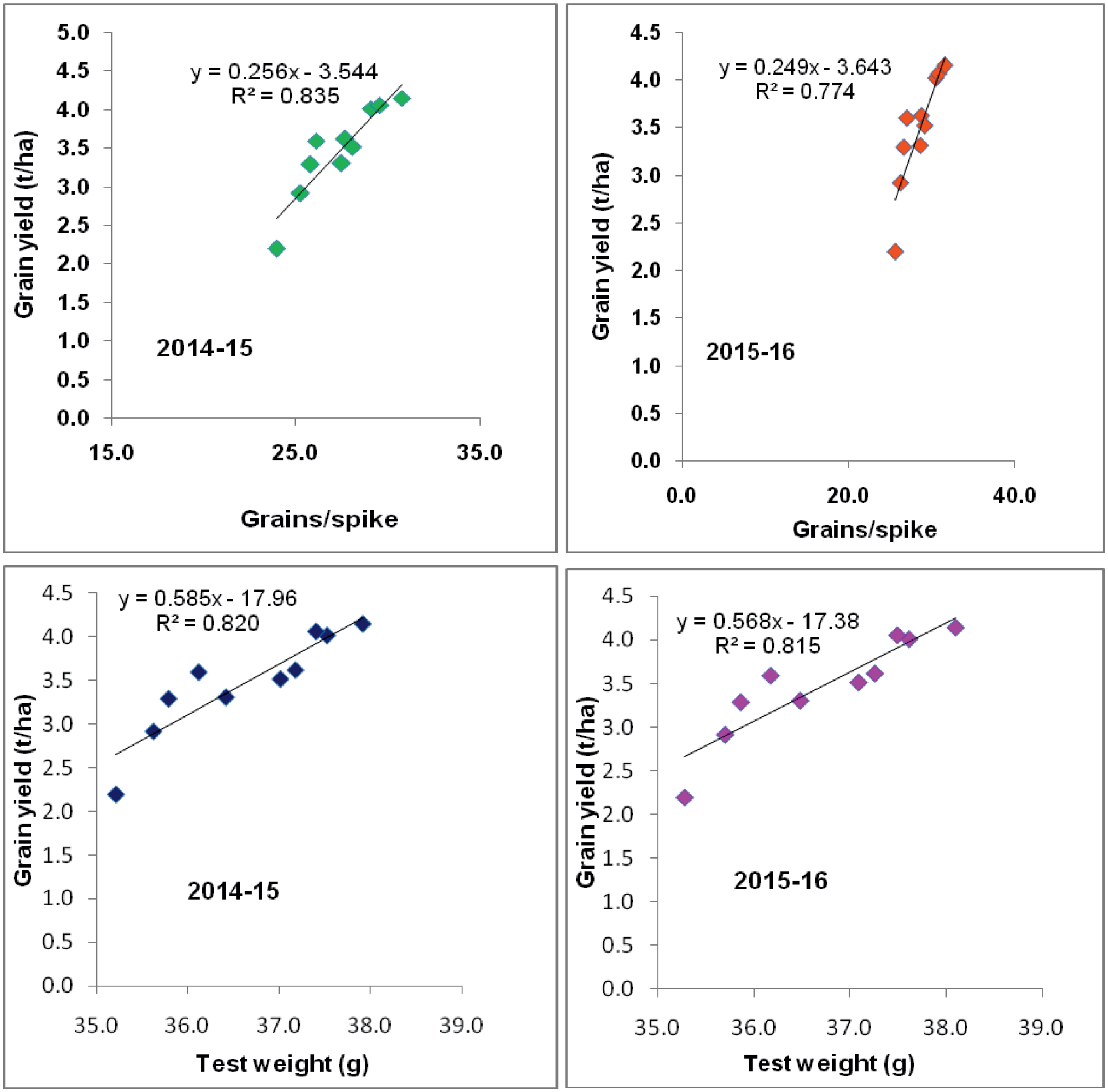

Fig. 2. Correlation of wheat grain yield with yield attributes, viz. grains/spike and test weight

weight/ear. Supply of nitrogen and phosphorus to soil might have accelerated various physiological processes in plants favouring increased yield in pearl millet. Kumawat *et al.,* (2018) reported increase in grain yield owing to 75% recommended fertilizer application might be because of better source and sink relationship.

It was concluded that 75% recommended dose of fertilizer (RDF) + FYM 5 t/ha + *Azotobacter* + phosphate-solubilizing bacteria (PSB) in wheat and 75% RDF in succeeding pearl millet should be applied for better nutrient management throughout the winter and rainy season, respectively, for obtaining higher yields and nutrient uptake under wheat–pearl millet cropping system.

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Table 2. Effect of direct and residual nutrient treatments on yield attributes and yield of pearl millet (pooled mean data of 2 years)

Treatment	Effective tillers (no./ m row length)	Ear length (cm)	Grain weight/ear (g)	Grain yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)
INM in wheat						
Control	12.61	16.21	13.66	1.20	2.37	3.57
50% RDF	13.58	16.38	13.91	1.25	2.43	3.68
75% RDF	14.00	16.77	14.26	1.27	2.47	3.75
100% RDF	14.21	16.69	14.38	1.29	2.50	3.80
50% RDF + FYM 5 t/ha	14.34	17.11	14.18	1.29	2.51	3.80
75% RDF + FYM 5 t/ha	15.16	17.72	14.54	1.35	2.61	3.95
100% RDF + FYM 5 t/ha	15.51	17.54	14.88	1.35	2.63	3.98
50% RDF + FYM 5 t/ha + *Azotobacter* + PSB	14.44	17.24	14.31	1.30	2.52	3.82
75% RDF + FYM 5 t/ha + *Azotobacter* + PSB	15.72	17.67	14.73	1.38	2.66	4.04
100% RDF + FYM 5 t/ha + *Azotobacter* + PSB	15.88	18.19	15.04	1.39	2.68	4.07
SEm±	0.28	0.81	0.50	0.02	0.03	0.04
CD (P=0.05)	0.82	NS	NS	0.05	0.09	0.12
Fertilizers in pearl millet						
Control	12.67	13.91	13.13	1.15	2.33	3.48
50% RDF		15.08	17.84	14.58	1.34	2.55
3.89						
75% RDF	15.89	19.70	15.45	1.43	2.73	4.16
SEm±	0.15	0.42	0.29	0.02	0.02	0.04
CD (P=0.05)	0.43	1.18	0.80	0.05	0.06	0.10

NS, Non-significant; RDF, recommended dose of fertilizer; FYM, farmyard manure (%); 0.52 N, 0.26 P and 0.49 K for 2014–15; FYM (%): 0.50, 0.27 and 0.56 for 2015–16; PSB, phosphate-solubilizing bacteria; 100% RDF (kg/ha)–120 N, 40 P_2O_5 and 20 K_2O for wheat; and 60 N and 40 P_2O_5 for pearl millet

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