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RESEARCH ARTICLE

Weeds response and control efficiency, greengram productivity and resource-use efficiency under a conservation agriculture-based maize-wheat-greengram system

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ABSTRACT

There has been a growing trend for achieving sustainable crop intensification without jeopardizing land productivity through conservation agriculture (CA). The CA has paved the way for cultivation of pulses in diverse cropping systems. A field experiment was conducted at ICAR-Indian Agricultural Research Institute, New Delhi during 2018-19 and 2019-20 cropping cycle with summer greengram in maize-wheat system to assess the effects of CA on weed interference, crop productivity and resource use efficiency. Results showed that CA-based practices with residue retention resulted in a considerable reduction in weed density and biomass when compared to conventional tillage (CT). Greengram yield parameters in CA were higher than in CT. The permanent broad bed (PBB) with residue retention (R) and recommended 100% N application (100N) (~PBB+R+100N) gave ~56% higher greengram grain yield than CT with considerably higher water productivity, nutrient-use efficiency and net returns. The adoption of CA practice involving PBB+R in greengram led to higher weed control efficiency and was more productive, remunerative and irrigation water-use efficient. Thus, it could potentially boost up the greengram productivity, profitability and resource-use efficiency under maize-wheat-greengram system in north-western Indo-Gangetic Plains (IGP) of India.

Keywords: Conservation agriculture, Residue retention, Greengram, Weed control efficiency, Nutrient use efficiency, Water productivity

INTRODUCTION

Based on land suitability and water availability of the northern and north-western India, maize–wheat system has been considered ideal for replacing the rice-based cropping systems (Ladha *et al*. 2016, Das *et al*. 2018, Gonçalves *et al*. 2019). Recently, conservation agriculture (CA) is being recommended for improving productivity, profitability and resource-use efficiency of cereal-based cropping systems (Hobbs *et al*. 2008, Ghosh *et al*. 2019, Das *et al*. 2020a, 2021). Several CA-based component technologies, such as zero tillage (ZT), raised bed planting, crop residue retention, crop diversification have been evaluated as alternatives to conventional practices in the IGP (Das *et al*. 2014, Bhattacharyya *et al*. 2015, Jat *et al*. 2020). Generally, fields in the indo-gangetic plains (IGP) remain fallow for 70–80 days (~up to June) after wheat harvest that allows for crop diversification. Diversified crop rotation including a legume, brown manuring under CA can lead to improved soil fertility, reduced pests/diseases infestations, improved weed management and increased crop yield stability (Behera *et al*. 2019, Li *et al*. 2019, Page *et al*. 2020, Das *et al*. 2020b, Ghosh *et al*. 2021). Because of their lower C:N ratio, legume residues also promote rapid nutrient mineralization (Hazra *et al*. 2019). Greengram (*Vigna radiata* L. Wilczek), a nutritious (24-28% protein, 60% carbohydrate) warm season grain legume crop with a short growing season (60-70 days), is ideal for sustainable intensification of CA-based maize-wheat systems (Nath *et al*. 2017). Multiple tillage operations required for seed-bed preparation (ploughing, harrowing, planking, *etc*.) in maize, wheat, and greengram can stretch the crop calendar and delay greengram sowing by 15-20 days under conventional farming. As a result, delayed pod harvest of greengram until mid-June may coincide with the onset of monsoon (rains), resulting in significant crop damage and reduced greengram

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yield. However, under CA, greengram can be effectively sown under ZT conditions using ZT drills or happy turbo seeders in a single tractor operation, saving time and allowing for early greengram sowing and harvesting (Hazra *et al.* 2019).

However, weeds become the major biological constraints in CA in the early years of adoption (Chauhan *et al.* 2012, Das *et al.* 2021). Weed seed accumulation under ZT is nearer to soil surface, where they are more likely to germinate but also face greater mortality risks due to weather variability and predation (Nichols *et al.* 2015). Simultaneously, weed seed production can be reduced indirectly due to crop residues, limiting weed growth through light interception, physical barriers, and allelopathy (Franke *et al.* 2007). Also, crop rotation could be an effective weed management strategy due to changes in production processes caused by diverse cropping systems, and weed species proliferation could be avoided (Buhler *et al.* 2001, Kaur *et al.* 2015). Bitew *et al.* (2022) observed lower weeds, higher soil organic matter, total N, and available P, and better soil water infiltration in CA-based maize-legume cropping systems. However, information on the comparative performance of CA (narrow, broad, flat beds with residue retention) and CT on greengram crop is scant. Therefore, this study was designed to compare the effects of CT and CA-based crop establishment on productivity, resource-use efficiency (water, nutrient, and weed control), and economics of greengram under a maize-wheat-greengram system to find out best tillage and crop establishment practice for long-term crop intensification.

MATERIALS AND METHODS

A field experiment was conducted during the summer seasons of 2018-19 and 2019-20 at Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi. The soil of the experimental site was clayey loam with a pH of 8.2, 0.60% organic C, medium available N (285 kg/ha) and P (18 kg/ha), and a high K (329 kg/ha). The experiment was laid out in a randomized complete block design with ten treatments and three replications. Greengram was sown as a component crop in a maize-wheat-greengram system, initiated during *Kharif* (*i.e.* rainy season) 2018-19. The experiment was a part of a long-term CA system, initiated in 2010. Different CA-based practices such as zero till (ZT) permanent narrow, broad and flat beds with and without retention of crops (maize, wheat and greengram) residues and 75% and 100% of the recommended dose of N were compared with conventional tillage (CT) practice. The treatments comprised of: conventional tillage without residue with 100% N (CT) and nine CA based treatments : permanent narrow bed (PNB) without residue with 100% N (PNB), permanent narrow bed with residue (R) with 75% N (PNB+R+75N), permanent narrow bed with residue with 100% N (PNB+R+100N), permanent broad bed (PBB) without residue with 100% N (PBB), permanent broad bed with residue with 75% N (PBB+R+75N), permanent broad bed with residue with 100% N (PBB+R+100N), flat bed (FB) without residue with 100% N (FB), flat bed with residue with 75% N (FB+R+75N) and flat bed with residue with 100% N (FB+R+100N) were followed in maize-wheat-greengram system.

The CT plots were prepared with a tractor-drawn disc plough followed by planking. There was no ploughing in CA-based treatments. The PNB plots had the dimension of 40 cm bed and 30 cm furrow. The PBB plots had a bed of 110 cm and a furrow of 30 cm. Wheat residues were retained in CA-based residue retention plots. To ensure smooth germination of greengram, the entire field was pre-sown irrigated. Greengram variety '*SML 832*' was sown during summer season with a seed rate of 20 kg/ha and 20 cm row spacing. Sowing was done using a tractor-drawn seed-cum-fertilizer drill in CT, a bed planter in PNB, while a turbo seeder in PBB and FB. Recommended dose of 150 kg N, 26.2 kg P and 33.1 kg K/ha was applied to both maize and wheat crops under 100% N treatment in both CA and CT plots, while in CA-based plots with 75% N, 112.5 kg N was applied. Residual effects of both the N treatments were studied in greengram. The recommended dose of 18 kg N and 20.1 kg P/ha through 100 kg DAP was applied in greengram as basal in all treatments.

At 30 DAS, total weed population (~density) and dry weight (~biomass) were measured. An area of 0.25 m^2 was selected randomly at 3 places using a quadrat (0.5 m × 0.5 m) and weed species were counted from that area and collected. First, weed samples were sun-dried for three days and then, kept in an oven at 70^0C to achieve a constant weight. Before analysis of variance, data on weed density and biomass were transformed using the square-root $[(x+0.5)]^{1/2}$ method (Das 1999) to reduce inherent variation in weed data.

Weed control efficiency (WCE) and weed control index (WCI) were calculated considering CT and CA-based plots are control and treated plots, respectively (Das 2008).

WCE = [(Weed density in control plot - weed density in treated plot)/ weed density in control plot] × 100

WCI = [(Weed biomass (g) in control plot-weed biomass (g) in treated plot)/ weed biomass (g) in control plot] × 100

Root nodules number and their dry weight were measured at flowering stage (~6 weeks after sowing) of greengram. Five mature plants were randomly chosen, and their pods were counted. Twenty pods were randomly chosen and manually threshed to estimate number of grains per pod. Matured pods were hand-picked from a net plot area of 10 m^2 and sun-dried. Dried pods from each plot were manually threshed, grains separated, weighed, and grain yield recorded. Stover yield was calculated from the greengram plants of net plot area after picking of pods.

In greengram, the nutrient-use efficiency was estimated in terms of partial factor productivity of nutrients (N and P) by dividing crop yield (kg/ha) by the amount of N and P applied (kg/ha). Water productivity (kg grain/ha/mm of water) was determined as per Bhushan *et al.* (2007) and Das *et al.* (2018) given below.

Water productivity (kg grain/ha/mm of water) = [Grain yield (kg/ha)/ Total water applied (mm)]

The cost of cultivation of various treatments was calculated using current market prices of various inputs used in the treatments. To determine the statistical significance of treatment effects, data on weed density, weed biomass, crop productivity, gross returns, net returns, net benefit: cost, water productivity, and partial factor productivity of nutrients were analyzed using analysis of variance (ANOVA) for a randomized completed block design using R (version 4.0.5) statistical software (Anonymous 2013). The Tukey Multiple Comparison Test was used to test for treatment differences at 5% level of significance.

RESULTS AND DISCUSSION

Weed interference and control efficiency

Weed flora in greengram comprised of *Setaria viridis* (L.) P.Beauv., *Dinebra retroflexa* (Vahl) Panz., *Cynodon dactylon* (L.) Pers. among grassy weeds; *Commelina benghalensis* L., *Digera arvensis* Forsk., *Euphorbia hirta* L., *Euphorbia microphylla* Lam., *Trianthema portulacastrum* L., *Amaranthus viridis* L. among broad-leaved weeds and *Cyperus rotundus* L., *Cyperus esculentus* L. among sedges. Among the different tillage, residue and crop establishment practices, CT recorded significantly higher weed density than CA-based practices. The CT practice recorded 51.1% and 47.9% higher weed density than PBB+R+75N and FB+R+75N during 2018-19 and 2019-20, respectively. The CA-based practices caused significant reduction in total weed density and biomass during both the years (**Figures 1** and **2**). It was observed that PBB+R+75N and FB+R+75N significantly reduced total weed density during 2018-19 and 2019-20, respectively. The treatment PBB+R+75N significantly reduced total weed biomass during 2018-19 and was found comparable with PBB+R+100N and PNB+R+100N. Similarly, during 2019-20, PBB+R+100N significantly decreased weed biomass and was statistically at par with PBB+R+75N and PNB+R+100N. PBB+R+75N and FB+R+75N registered the highest weed control efficiency during 2018-19 and 2019-20, respectively (**Table 1**). PBB+R+75N and PBB+R+100N also recorded the highest weed control index during 2018-19 and 2019-20, respectively (**Table 1**). CA-based practices with residue retention significantly reduced total weed density and biomass, increased weed control efficiency and weed control index in greengram due to smothering effect of residues on weed emergence and growth (Ghosh *et al.* 2021) and enabled the crop to gain an advantage over weeds while also sustaining more productivity (Nath *et al.* 2016, Baghel *et al.* 2020). Zero tillage with crop residue retention can be a vital multi-tactic approach to managing weed population dynamics and successfully incorporating CA into crop rotations (Nath *et al.* 2017).

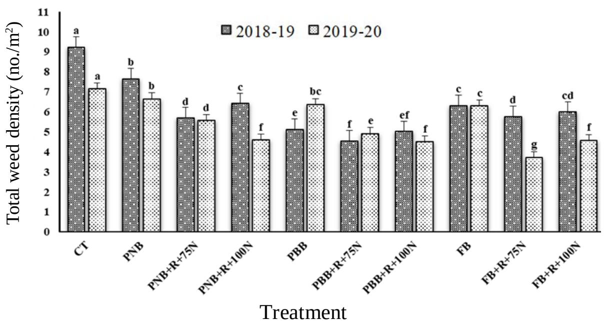

Figure 1. Total weed density in greengram as affected by tested treatments at 30 DAS

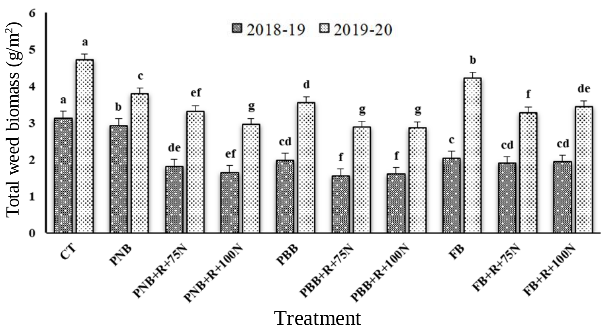

Figure 2. Total weed biomass in greengram as affected by tested treatments at 30 DAS

Table 1. Weed control efficiency and weed control index in greengram as affected by tested treatments

Treatment	Weed control efficiency (WCE) (%)		Weed control index (WCI) (%)	
	2018-19	2019-20	2018-19	2019-20
CT	0.0	0.0	0.0	0.0
PNB	16.3	5.6	6.7	19.5
PNB+R+75N	38.0	21.1	42.2	29.7
PNB+R+100N	30.4	35.2	47.3	37.2
PBB	44.6	9.9	36.7	24.8
PBB+R+75N	51.1	31.0	50.2	38.9
PBB+R+100N	45.7	36.6	48.9	39.1
FB	31.5	11.3	35.1	10.6
FB+R+75N	37.0	47.9	39.3	30.6
FB+R+100N	34.8	35.2	38.3	27.2

Refer materials and methods for treatment details

Effect on greengram nodules growth and yield variables

CA-based practices with residue retention influenced nodulation characteristics of greengram and had a greater influence on nodule growth of greengram (**Table 2**). Under PBB+R+100N, the number of nodules and nodule dry weight per plant were significantly higher during both the years. The numbers of pods per plant and test weight were found to be significantly higher under CA-based practices. During both the years, PBB+R+100N recorded significantly higher number of pods per plant (**Table 2**). In case of test weight, the treatment FB+R+100N recorded significantly higher test weight (42.03 g) than rest of the practices during 2018-19. But, it remained at par with the CA-based practices with residue retention. During 2019-20, PBB+R+100N recorded significantly higher test weight (42.16 g) and it was found to be statistically at par with FB+R+100N. However, the number of greengram seeds per pod did not vary significantly among the treatments during both the years. The conservation agriculture-based practices with residue retention contributed to greater number of pods per plant, more seeds per plant, and improved nodule growth in greengram, resulting in higher test weight in these practices.

Effect on greengram productivity

CA-based practices also increased greengram yield significantly (**Table 3**). The results revealed that among CA-based practices, treatments with residue retention resulted in higher greengram productivity than treatments with residue removal. During 2018-19, FB+R+100N, resulted in significantly higher grain yield (1.10 t/ha) and stover yield (3.24 t/ha) than rest of the practices. It recorded 46.7% and 16.9% higher grain and stover yield, respectively than CT practice. PBB+R+100N was observed to be the next best treatment. During 2019-20, PBB+R+100N significantly recorded the highest grain (1.17 t/ha) and stover (3.78 t/ha) yield and it was found to be statistically at par with FB+R+100N and PNB+R+100N treatments. The treatment PBB+R+100N achieved yield improvement to the tune of 69.6% and 42.6% in grain and stover yield, respectively as compared to CT. Greengram yield was significantly higher under CA-based practices with residue retention due to improved yield attributes under CA as compared to CT. Weed interference is inversely related to crop yield (Das and Yaduraju 2011). The weed suppression, increased soil water retention and availability, and stabilization of soil nutrients due to a long-term CA practice created a favourable environment for improving yield attributes, resulting in increased yield in greengram (Bhattacharyya *et al*. 2013, Das *et al*. 2018). The residual effects of previous crop nutrient

Table 2. Nodule characteristics and yield parameters of greengram as affected by tested treatments

Treatment	No. of nodules/ plant		Nodule dry weight/ plant (mg)		No. of pods/ plant		No. of seeds/ pod		Test weight (g)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
CT	27.7^{c}	29.3^{c}	66.73^{e}	67.13^{f}	19.7^{b}	21.1^{f}	7.6	7.3	38.36^{b}	37.91^{e}
PNB	28.3^{c}	32.7^{bc}	89.76^{bc}	89.64^{cd}	20.7^{b}	22.8^{ef}	8.4	8.1	39.97^{ab}	38.94^{d}
PNB+R+75N	30.3^{bc}	35.3^{ab}	90.42^{bc}	92.09^{bcd}	23.3^{ab}	24.9^{cdef}	8.6	8.3	40.41^{ab}	40.25^{bc}
PNB+R+100N	33.0^{ab}	36.3^{ab}	102.73^{a}	100.49^{abc}	27.1^{ab}	28.8^{abc}	8.7	8.5	41.39^{a}	41.04^{b}
PBB	29.7^{bc}	33.0^{bc}	81.56^{cd}	82.03^{de}	20.3^{b}	23.3^{def}	8.5	8.1	40.20^{ab}	39.64^{cd}
PBB+R+75N	31.3^{abc}	35.0^{ab}	97.21^{ab}	98.08^{abc}	26.7^{ab}	27.7^{abcd}	8.6	8.3	41.22^{a}	40.94^{b}
PBB+R+100N	35.7^{a}	37.3^{a}	105.76^{a}	106.92^{a}	29.0^{a}	30.3^{a}	8.9	9.0	41.81^{a}	42.16^{a}
FB	30.0^{bc}	33.0^{bc}	72.75^{de}	74.07^{ef}	22.3^{ab}	23.6^{def}	8.3	8.5	40.11^{ab}	40.19^{bc}
FB+R+75N	30.7^{bc}	34.3^{ab}	95.97^{ab}	96.18^{abc}	24.0^{ab}	25.6^{bcde}	8.6	8.6	41.13^{a}	40.72^{b}
FB+R+100N	32.0^{abc}	36.7^{ab}	100.15^{ab}	103.06^{ab}	28.6^{a}	29.6^{ab}	8.7	8.8	42.03^{a}	42.08^{a}

Refer materials and methods for treatment details management (maize and wheat) also aided in increasing greengram yield attributes as well as yield. Among all the CA-based practices, PBB+R+100N was found superior in significantly increasing greengram yield attributes, as a result higher productivity was observed in this practice. When compared to conventional or flat planting, bed planting techniques had various advantages in terms of higher productivity owing to a variety of factors, including lower weed density, less competition for resources, enhanced soil water regimes, better aeration, and nutrient use (Das *et al.* 2013).

Effect on economics of greengram cultivation

Tillage, residue and crop establishment practices had significant impacts on economics in greengram cultivation (**Table 4**). The CA-based practices with residue removal recorded 16.8% and 15.5% lesser cost of cultivation than CT during 2018-19 and 2019-20, respectively, while the CA-based practices with residue retention registered on an average 3.5% higher cost of cultivation than CT. During 2018-19, FB+R+100N significantly recorded higher gross returns (80.20 × 10^3 ₹/ha), net returns (51.35 × 10^3 ₹/ha) and net benefit: cost (B:C) ratio (1.78) and was found comparable with CA-based practices with residue retention. During 2019-20, PBB+R+100N was found to register significantly higher gross returns (86.27 × 10^3 ₹/ha), net returns (55.52 × 10^3 ₹/ha) and net B:C ratio (1.81). This treatment was found to be comparable with FB+R+100N and PNB+R+100N. The CA-based practices recorded 7-46.1% higher gross returns, 29-89.8% higher net returns and 40.2-83.5% higher net B: C ratio during 2018-19. CA-based residue removal practices resulted in lower cultivation costs due to less use of machinery, labour, and fuel. Due to the cost of residue application, CA-based practices with residue retention resulted in higher cultivation costs than CT. However, residue retention practices significantly increased greengram yield. Higher yields in residue-retained treatments offset the cost of residue retention, resulting in higher net returns and net B: C.

Table 3. Productivity of greengram as affected by tested treatments

Treatment	2018-19			2019-20		
	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
CT	0.75^{d}	2.77^{d}	21.3	0.69^{f}	2.65^{c}	20.9
PNB	0.81^{d}	2.84^{cd}	22.2	0.76^{f}	2.78^{c}	21.7
PNB+R+75N	0.93^{bc}	3.01^{abcd}	23.7	0.84^{def}	2.95^{bc}	22.2
PNB+R+100N	1.06^{a}	3.20^{ab}	24.9	1.02^{abc}	3.41^{ab}	23.2
PBB	0.82^{cd}	2.86^{bcd}	22.3	0.79^{ef}	2.81^{c}	21.8
PBB+R+75N	1.01^{ab}	3.11^{abc}	24.4	0.97^{bcd}	3.37^{ab}	22.3
PBB+R+100N	1.08^{a}	3.19^{ab}	25.3	1.17^{a}	3.78^{a}	23.6
FB	0.80^{d}	2.80^{cd}	22.3	0.80^{ef}	3.00^{bc}	21.1
FB+R+75N	1.02^{ab}	3.10^{abcd}	24.8	0.95^{cde}	3.35^{ab}	22.1
FB+R+100N	1.10^{a}	3.24^{a}	25.6	1.12^{ab}	3.67^{a}	23.5

Refer materials and methods for treatment details

Table 4. Greengram economics as affected by tested treatments

Treatment	2018-19				2019-20			
	Cost of cultivation (×10^3 ₹/ha)	Gross returns (×10^3 ₹/ha)	Net returns (×10^3 ₹/ha)	Net B:C	Cost of cultivation (×10^3 ₹/ha)	Gross returns (×10^3 ₹/ha)	Net returns (×10^3 ₹/ha)	Net B:C
CT	27.84	54.90^{d}	27.05^{d}	0.97^{d}	29.74	51.29^{f}	21.55^{e}	0.72^{e}
PNB	23.84	59.45^{d}	35.61^{c}	1.49^{abc}	25.74	56.13^{f}	30.38^{de}	1.18^{cd}
PNB+R+75N	28.84	67.99^{bc}	39.15^{bc}	1.36^{c}	30.74	61.94^{def}	31.19^{de}	1.01^{de}
PNB+R+100N	28.84	76.86^{a}	48.01^{a}	1.66^{ab}	30.74	75.56^{abc}	44.81^{abc}	1.46^{abc}
PBB	23.84	59.96^{cd}	36.12^{c}	1.51^{abc}	25.74	58.27^{f}	32.53^{de}	1.26^{bcd}
PBB+R+75N	28.84	73.30^{ab}	44.46^{ab}	1.54^{abc}	30.74	71.52^{bcd}	40.78^{bcd}	1.33^{bcd}
PBB+R+100N	28.84	78.52^{a}	49.67^{a}	1.72^{ab}	30.74	86.27^{a}	55.52^{a}	1.81^{a}
FB	23.84	58.74^{d}	34.90^{cd}	1.46^{bc}	25.74	59.40^{ef}	33.66^{cd}	1.31^{bcd}
FB+R+75N	28.84	74.17^{ab}	45.33^{ab}	1.57^{abc}	30.74	70.33^{cde}	39.58^{cd}	1.29^{bcd}
FB+R+100N	28.84	80.20a	51.35^{a}	1.78^{a}	30.74	82.63^{ab}	51.89^{ab}	1.69^{ab}

Refer materials and methods for treatment details

Water productivity

Water consumption varied according to tillage, residue and crop establishment practices. Water productivity was found to be significantly higher in CA-based practices due to less water use in CA plots compared to CT plots (**Figures 3** and **4**). Among CA-based practices, PBB+R treatment consumed 30.3% and 29.9% less water than CT during 2018-19 and 2019-20, respectively. Water productivity increased as a consequence of both increased greengram yield and irrigation water savings under PBB+R+100N. Weeds, being ubiquitous in nature, intensely competitive, persistent, and hardy in comparison to cultivated crops, impede agricultural operations and reduce resource use efficiency (Das 2008, Kaur *et al.* 2018, Das *et al.* 2020b). The increased weed suppression under CA-based residue retained practices led to increased soil water conservation under these practices (Ghosh *et al.* 2021). Also, CA-based practices involving crop residue retention increased soil water storage by reducing soil evaporation (Nath *et al.* 2017, Parihar *et al.* 2017) which increased greengram yield and, as a result, both irrigation water productivity and total water productivity were significantly improved under these practices. When compared to PNB+R+100N, PBB+R+100N retained more residues due to more uniform distribution of residue on top of the broad beds. This resulted in improved infiltration and water conservation on beds (Das *et al.* 2018), reduced run-off and erosion, weed control, higher fertilizer usage efficiency, and higher productivity under PBB+R+100N as compared to other practices.

Partial factor productivity of N and P

The CT treatment had the lowest partial factor productivity of N and P during both years (**Figures 5** and **6**). Among CA-based practices with residue retention, FB+R+100N registered significantly higher PFP of N (61.3 kg grain/ kg N) during 2018-19 and was found comparable with PBB+R+100N, PNB+R+100N, PBB+R+75N and FB+R+75N. During 2019-20, PBB+R+100N registered significantly higher PFP of N (65 kg grain/ kg N) and was found to be statistically at par with FB+R+100N and PNB+R+100N. The same trend was observed in recording partial factor productivity of P also. Crop production requires a variety of agricultural inputs, including nutrients/fertilizers and water (Kaur *et al.* 2018). These resources are critical in crop-weed interactions. Fertilizer application may benefit weeds more than crops because weeds absorb nutrients faster and more efficiently than crop plants (Das 2008). The significant reduction in weed growth in

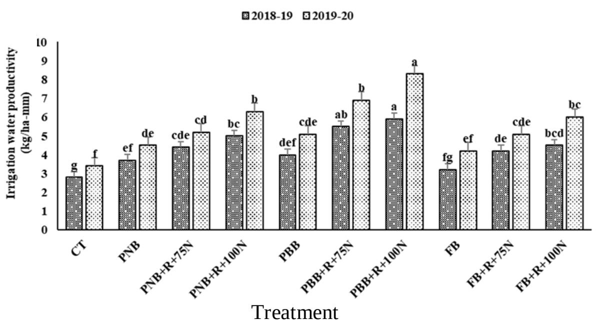

Figure 3. Irrigation water productivity in greengram as affected by tested treatments

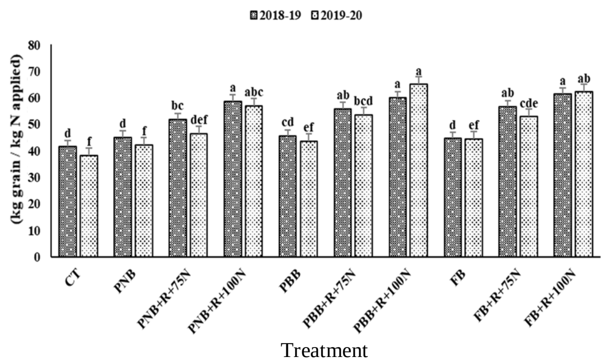

Figure 5. Partial factor productivity of N in greengram as affected by tested treatments

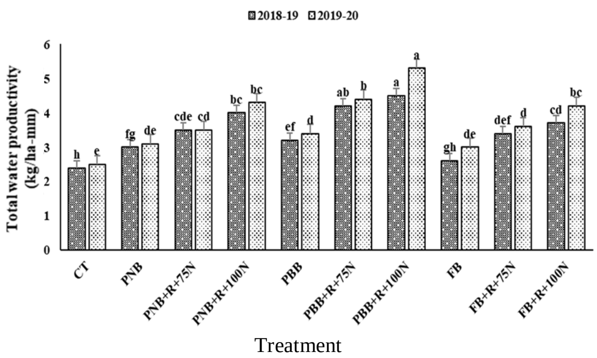

Figure 4. Total water productivity in greengram as affected by tested treatments

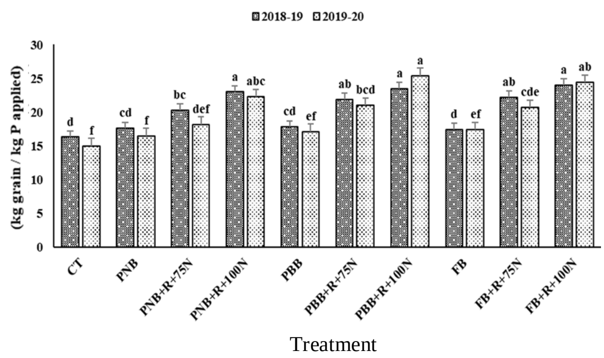

Figure 6. Partial factor productivity of P in greengram as affected by tested treatments

CA-based practices as well as the beneficial effects of crop residue retention on crop growth led to higher crop productivity per unit of nutrient application, which resulted in significantly higher PFP of nutrients in CA-based practices than CT indicating efficient utilization of N and P for greengram growth and productivity.

Thus, the conservation agriculture-based permanent broad bed with residue retention (PBB+R+100N) resulted in significant improvement in crop productivity, profitability, weed control efficiency, water productivity and nutrient use efficiency in greengram under the maize-wheat-greengram system. It can be recommended for sustainable greengram production in north-western Indo-Gangetic Plains of India under the maize-wheat-greengram sequence.

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