

Original Research Article

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Residual Effect of Crop Residue and Potassium Management on Greengram Productivity, Soil and Canopy Temperature Depression in Maize and Wheat under Zero Tillage Maize-Wheat-Greengram Cropping System

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ABSTRACT

A field experiment was conducted in *kharif*, *rabi* and *summer* seasons of 2014-15 to 2015-16 at ICAR-IARI, New Delhi to study the residual effect of crop residue (CR) and potassium (K) management on greengram productivity, soil and canopy temperature depression (CTD) in maize and wheat under zero tillage maize-wheat-greengram cropping system. The experiment was laid out in split plot design with four CR levels (0, 2, 4 and 6 tha^{-1}) and five K levels [0, 50%, 100%, 150% RDK (recommended dose of K) and 50%RDK+Potassium solubilizing bacteria, KSB]. Greengram was sown as summer season crop to study the residual effect of treatments imposed for maize and wheat crops without any fertilization in greengram. Results revealed that greengram seed yield was significantly higher (46.93-51.02%) with 4-6.0 tha^{-1} CR as compared to no CR. Similarly, 50% RDK + KSB recorded significantly higher grain yield over No K (56.52%-63.15%). Furthermore, soil temperature non-significantly decreased in maize and increased in wheat with 4.0-6- tha^{-1} CR compared to no residue applied plot throughout the growing period. However, among residue management practices highest value of CTD was observed with 6-4.0 tha^{-1} CR. K management practices did not influence much on soil temperature and CTD except KSB treated plot. Therefore, CR retention at 4-6.0 tha^{-1} and application of 50% RDK + KSB could have a positive residual impact on summer greengram productivity enhancement by regulating soil temperature with favourable CTD in maize and wheat crops under conservation agriculture-based maize-wheat-greengram cropping system.

Keywords

Conservation agriculture, Crop rotation, KSB, Summer greengram and Yield

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Introduction

Cereal based cropping systems such as rice-wheat and maize-wheat are the dominant cropping systems in Indo-Gangatic Plains

(IGP) of India (Balaji *et al.*, 2018). Continuous growing of cereal-cereal cropping system leads to deterioration in soil health, depletion of soil nutrients, environmental quality and crop productivity (Daveri *et al.*,

2012). Furthermore, in IGP fields remains fallow for 70-80 days during summer after harvest of winter crops (Meena *et al.*, 2015). Therefore, adoption of alternate cropping system with inclusion of legumes like greengram in summer having assured irrigation under different cereal-based cropping system provide scope to enhance crop productivity besides improving overall health of soil with additional financial benefit to farmers under IGP areas (Meena *et al.*, 2015; Balaji *et al.*, 2018). Conventional tillage delays the sowing of summer greengram by 7-10 days due to intensive tillage practices followed by farmers for optimum seed bed preparation (Chouhan *et al.*, 2005).

Consequently, under such condition resource conserving technologies (RCTs) like zero tillage and residue retention have emerged over the past 2–3 decades as a means of achieving the sustainability of intensive cropping systems (Sharma *et al.*, 2012). In cereal based cropping system huge amount of residue (23%) is generated in India (Raghavendra *et al.*, 2018). About 75% of K-uptake by cereal crops can be retained in crop residues, making them valuable nutrient sources for different crops in sequence cropping system (Singh 2003). In IGP, farmers burn crop residue in open field that leads to not only emission of harmful gases and air pollutants into the atmosphere (Raghavendra *et al.*, 2020), but also causes loss of nutrients. To minimize this problem, recycling of nutrients (N, P and K) through crop residue retention is one of the desired options that may lead to effective disposal and help overcome the deficiencies of other nutrients, such as S, Zn and B deficiencies, which are widespread in the IGP region (Prasad 2005). Potassium (K) is the third macro-nutrient required by the crop plants and plays a significant role in growth and development, and provides resistance to biotic

and abiotic stresses (Bagyalakshmi *et al.*, 2012). Average yield loss in cereal based cropping system due to K-omission ranged from 700-715 kg ha⁻¹ (Majumdar *et al.*, 2012).

This suggests that skipping application of K in cereal crops will cause variable yield and economic loss to the farmers of the region and will affect overall cereal production in the country (Raghavendra *et al.*, 2020a). Further, there are no reserves of K-bearing minerals in India for production of commercial K-fertilizers and the whole consumption of K-fertilizers imported which involves huge amount of foreign exchange. This necessitates the need to find an alternate K source like potassium solubilising bacteria (KSB). KSB have been reported to increase K availability in soils and result in its increased uptake by crops in different cropping system (Sheng *et al.*, 2003; Raghavendra *et al.*, 2020a).

Generally, the agro inputs (organic manure, residue and fertilizers) applied to main crop leaves residual effect to succeeding crops. The positive influence of residual effect of agro inputs on productivity of several crops were reported by many authors in different cropping systems (Mathew *et al.*, 2003; Jena *et al.*, 2006; Bharathi and Poongothai 2008; Bilkis *et al.*, 2018 and Koireng *et al.*, 2018). Therefore, by keeping all these in view, present investigation was under taken to study the residual effect of crop residue and K management practices on greengram productivity and to know the impact of CR, inorganic K and bio-fertilizers (KSB) on soil temperature dynamics and canopy temperature depression in maize and wheat under zero tillage maize-wheat-greengram cropping system.

Materials and Methods

The field experiment was conducted during *kharif*, *rabi* and *summer* seasons of 2014-15

and 2015-16 at the research farm of the ICAR-Indian Agricultural Research Institute, New Delhi located at 28.35°N latitude and 77.12°E longitude and 228.6 m above mean sea level (MSL). Delhi falls under the agro-climatic zone Trans-Gangatic Plains. There was a lot of variation in total rainfall received during *kharif* 2014 and 2015 with 395.4 and 633.10 mm and *rabi* 2014-15 and 2015-16 were 315.80, 19.80 mm of maize and wheat crops, respectively.

The mean maximum temperature (34.27, 33.47°C), mean minimum temperature (22.83, 22.13°C) for *kharif* maize and similarly for wheat mean maximum temperature (24.27, 26.81°C), mean minimum temperature (10.36, 9.77°C) during both years. Greengram cropping period received mean maximum temperature (39.86, 39.97°C), mean minimum temperature (24.4, 23.49°C), total rainfall (87, 40 mm), mean relative humidity (52.51, 55.01%), mean sunshine hours (7.34, 7.06 hrs) and mean evaporation (8.90, 8.64 mm) during 2015 and 2016, respectively throughout the growing period. The experimental soil belongs to Mehrauli series (Udic Ustochrepts) with the following soil characteristics: pH 8.33, EC 0.37 dSm⁻¹, soil organic carbon (SOC) 0.43%, KMnO₄ oxidizable N 143 kg ha⁻¹, NaHCO₃ extractable P (pH 8.5) 13.5 kg ha⁻¹, and 1N ammonium acetate extractable K 245 kg ha⁻¹ and bulk density 1.52 Mg m⁻³, at the initiation of the experiment. All these parameters were analysed by adopting standard procedures (Boruah and Barthakur 1999).

The experiment was laid out in split plot design in twenty treatment combinations with four crop residue (CR) levels (No CR, 2 t ha⁻¹ CR, 4 t ha⁻¹ CR and 6 t ha⁻¹ CR) in main plot and five potassium levels (No K, 50% RDK (Recommended dose of Potassium), 100% RDK, 150% RDK and 50% RDK+KSB (Potassium solubilizing bacteria)) in sub plots

and replicated thrice. Maize (PMH 4), wheat (HD CSW 18) and greengram (Pusa Vishal) were sown at 60 x 30 cm, 20 cm, and 20cm respectively with the help of turbo seeder with seed rate of 20 kg ha⁻¹ for maize, 100 kg ha⁻¹ for wheat and 20 kg ha⁻¹ for greengram. Recommended dose of fertilizer for maize and wheat (150:80:60 kg N, P₂O₅ and K₂O ha⁻¹) was placed below the seed zone at sowing as per the treatment.

Greengram was grown with residual effect of treatments applied to maize and wheat crops without any fertilizer application. In maize and wheat crops full dose of P and K and half of the dose of N were applied as basal at sowing. The remaining N in wheat was top dressed in two equal splits after the first and second irrigation. In maize remaining N was top dressed at 35 days after sowing. Seeds of both maize and wheat crops were treated with potassium solubilizing bacteria (KSB) @ 50 ml acre⁻¹ as per treatment. Sun dried chopped residues of the wheat and maize crops of previous season were applied at different levels to maize and wheat crops respectively by retaining on the soil surface as mulch in all treatments except control after sowing of crops.

Depth of irrigation water was kept at 6-7 cm and number of irrigations applied in maize and wheat 4 and 5 during 2014-15 and 3 and 6 during 2015-16, respectively. To provide an ideal weed free environment to maize crop the Pendimethalin @ 1.00 kg a.i. ha⁻¹ along with Atrazine (@ 0.75 kg a.i. ha⁻¹) was sprayed as pre-emergence at 1-2 days after sowing. To manage weeds in wheat, Isoproturon @ 0.75 kg a.i. ha⁻¹ along with 2, 4D @ 0.25 kg a.i. ha⁻¹ was applied as post emergence at 30 days after sowing.

Data on greengram was recorded as per the standard procedure. Matured pods from the net plot area of 16.66 x 2 m² was picked

manually and dried in the sun. Two pickings of pods were taken for green gram and left them on threshing floor to get properly dried. Dried pods from each treatment plots were weighed and threshed manually. Separated seeds were again weighed and recorded. Grain weight from each treatment was subtracted from their respective pod weight to get shell weight of the pods.

To estimate the haulm yield of greengram of each plot, a quadrant of 0.70 m x 0.70 m was used to take residue samples from the respective net plot area. The haulm samples were sun dried and weighed, and proportionate weight of sun-dried haulm from the quadrant area were used to estimate the total green gram residue of each plot. After harvest of greengram, glyphosate was sprayed on leftover part. The weight of grain and straw was worked out and expressed in $t\ ha^{-1}$.

The canopy temperature depression (CTD) relative to the air temperature was measured with the hand held infra-red thermometer at different intervals of maize and wheat. Two readings of canopy temperature were taken from the individual experimental unit only on the sunny days and in the afternoon. Simultaneously the ambient air temperature was also recorded. The canopy temperature depression was calculated with the formula given below:

Canopy Temperature Depression ($^{\circ}C$) = Air temperature ($^{\circ}C$) – Canopy temperature ($^{\circ}C$)

Soil temperature in maize and wheat recorded in different interval with help of soil thermometer. All the data obtained from maize, wheat and greengram crops for consecutive 2 years, 6 seasons were statistically analysed using the F-test as per the procedure given by Gomez and Gomez (1984).

Results and Discussion

Residual effect of crop residue and K management practices on summer greengram productivity

The data pertaining to pod, seed, haulm, biomass yield and harvest index of summer greengram were significantly influenced by the residual effect of crop residue and K management practices and these are presented in Table 1. The application of residue at 4.0-6.0 tha^{-1} CR in maize and wheat registered significantly higher pod yield, seed yield, haulm yield, biomass yield and harvest index over No CR and 2.0 tha^{-1} CR. Similarly, combined application of K fertilizer with KSB (50% RDK+KSB) gave significantly greater pod yield, seed yield, haulm yield, biomass yield and harvest index over No K and 50% RDK. However, 50% RDK+KSB was found non-significant with 100% RDK and 150% RDK. Interaction effect of CR and K management for different parameters of greengram was found non-significant. It was noticed that greengram yield was gradually increased over the years in the residue and K fertilization compared to no residue and no K. Further, data indicated that previous season crop residue significantly increased the productivity of greengram. The yield varied significantly in the order of 4.0 tha^{-1} CR > 6.0 tha^{-1} CR > 2.0 tha^{-1} CR > No CR in residue treatment and 50% RDK+KSB > 100% RDK > 150% RDK > 50% RDK > No K. Better soil health, nutrient availability, water and nutrient uptake resulted in better growth and residual effect under residue retention on zero-tilled soil might have offered cumulative effect for improved productivity of summer greengram. Due to above benefits inclusion of greengram in the double cereal-based crop rotation under conservation agriculture practices were also suggested as future drivers of agricultural change in the north-western IGP (Gathala *et al.*, 2013, Meena *et al.*, 2015 and Bilkis *et al.*, 2018).

Table.1 Residual effect of crop residue and potassium management practices on summer greengram yield and harvest index under zero till maize- wheat-greengram cropping system

Treatment	Greengram									
	2015					2016				
	Pod yield (tha ⁻¹)	Seed yield (tha ⁻¹)	Haulm yield (tha ⁻¹)	Biomass yield (tha ⁻¹)	Harvest index (%)	Pod yield (tha ⁻¹)	Seed yield (tha ⁻¹)	Haulm yield (tha ⁻¹)	Biomass yield (tha ⁻¹)	Harvest index (%)
Crop residue management practices (CRM)										
No CR	0.69	0.49	2.03	2.71	17.79	0.90	0.61	2.14	3.03	20.01
2.0 tha⁻¹CR	0.78	0.57	2.21	2.99	19.01	0.99	0.75	2.23	3.22	23.23
4.0 tha⁻¹CR	0.95	0.74	2.45	3.40	21.52	1.09	0.92	2.51	3.60	25.34
6.0 tha⁻¹CR	0.93	0.72	2.44	3.37	21.20	1.08	0.90	2.50	3.58	24.82
SEm±	0.02	0.02	0.02	0.04	0.51	0.03	0.03	0.02	0.04	0.97
LSD (P=0.05)	0.07	0.07	0.08	0.14	1.77	0.09	0.11	0.08	0.15	3.34
Potassium management practices (PM)										
No K	0.67	0.46	1.98	2.65	17.19	0.86	0.57	2.02	2.87	19.81
50% RDK	0.81	0.56	2.14	2.95	18.72	0.94	0.66	2.19	3.13	21.06
100% RDK	0.90	0.71	2.43	3.34	21.12	1.09	0.91	2.51	3.60	25.24
150% RDK	0.89	0.70	2.41	3.30	21.10	1.08	0.90	2.50	3.58	24.95
50% RDK+KSB	0.92	0.72	2.43	3.35	21.27	1.09	0.93	2.52	3.61	25.69
SEm±	0.04	0.03	0.04	0.07	0.87	0.02	0.03	0.04	0.05	0.89
LSD (P=0.05)	0.12	0.09	0.12	0.19	2.51	0.07	0.08	0.11	0.14	2.57
CRM x PM	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

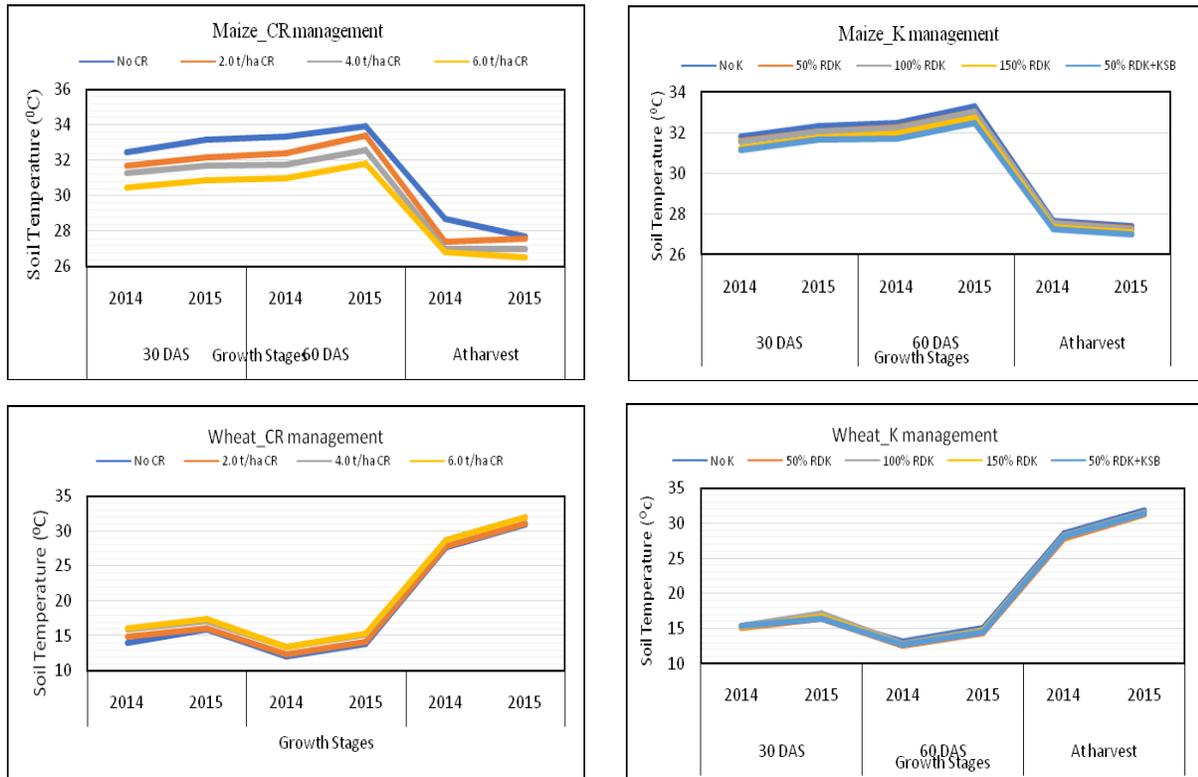
CR: Crop residue, RDK: Recommended dose of potassium, KSB: Potassium solubilising bacteria, NS: Non-significant

Table.2 Effect of crop residue and potassium management practices on canopy temperature depression (°C) in maize and wheat at different growth stages of zero tillage maize-wheat-greengram cropping system

Treatment	Maize						Wheat					
	Canopy temperature depression (°C)											
	30 DAS		60 DAS		At harvest		30 DAS		60 DAS		At harvest	
	2014	2015	2014	2015	2014	2015	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Crop residue management practices (CRM)												
No CR	3.36	3.26	1.86	1.97	1.71	1.97	3.94	3.33	3.61	4.96	4.69	4.02
2.0 tha⁻¹CR	3.88	3.91	2.47	2.31	2.68	2.52	3.28	4.19	3.39	4.12	4.82	4.66
4.0 tha⁻¹CR	4.51	4.87	3.59	3.61	2.02	2.21	4.19	4.83	4.71	4.83	3.57	4.74
6.0 tha⁻¹CR	5.00	4.65	3.71	4.67	3.35	3.51	3.90	5.25	3.90	4.74	5.99	4.70
SEm±	0.94	0.66	0.59	0.72	1.39	0.85	0.52	0.51	0.52	0.53	0.66	0.78
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Potassium management practices (PM)												
No K	4.12	4.10	3.13	1.97	2.04	1.95	2.73	3.95	3.29	4.35	3.58	2.81
50% RDK	4.75	3.65	3.24	2.98	1.22	2.24	4.06	4.31	4.10	3.82	3.78	4.05
100% RDK	4.37	4.23	2.50	3.48	2.40	2.35	3.90	4.76	3.49	5.40	5.41	4.73
150% RDK	4.05	4.58	2.34	3.98	2.82	2.59	4.41	4.80	4.58	5.02	4.68	5.35
50% RDK+KSB	3.65	4.31	3.33	3.30	3.73	3.64	4.03	4.18	4.06	4.74	6.39	5.73
SEm±	1.06	1.26	0.83	1.04	0.86	0.70	0.53	0.39	0.52	0.66	0.78	0.67
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CRM x PM	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

CR: Crop residue, RDK: Recommended dose of potassium, KSB: Potassium solubilising bacteria, DAS: Days after sowing, NS: Non-significant

Fig.1 Effect of crop residue and K management practices on soil temperature ($^{\circ}\text{C}$) in maize and wheat at different growth stages of zero tillage maize-wheat cropping system



CR: Crop residue, RDK: Recommended dose of potassium, KSB: Potassium solubilising bacteria, DAS: Days after sowing

Effect of residue and K management practices on canopy temperature depression

Crop residue and K fertilization did not significantly influence the canopy temperature depression (CTD) in both crops (Table 2). However, among residue management practices highest value of CTD was observed with 6.0 t ha^{-1} CR followed by 4.0 t ha^{-1} CR and these were not significantly higher than no residue plot at different growth stages of maize and wheat. However, different K management practices showed apparently very less variation in CTD at 30, 60 days after sowing (DAS) and at harvest of both the crops. The lush crop growth was obtained with residue applied plot through which higher transpiration was created by canopy coolness as of ambient temperature,

hence higher CTD values were obtained with residue applied plot. The similar results were also reported by Jakhar (2016).

Effect of residue and K management practices soil temperature

The soil temperature recorded at 5.0 cm depth in the central rows of each treatment plot was observed in the afternoon (2.30 PM) at 30 days after sowing (DAS), 60 DAS and harvest of maize and wheat (Figure 1). Comparatively lower soil temperature was observed with the application of 6.0 t ha^{-1} CR compared to no residue (No CR) treatment throughout the growth period of maize; though higher difference of temperature was observed up to 60 DAS. It was also observed that the soil temperature in 4.0 t ha^{-1} CR was ranging between $2.0\text{-}6.0 \text{ t ha}^{-1}$ CR. Mean soil

temperature increased in the observation taken at 30 DAS to 60 DAS and declined thereafter in all the treatments of crop residue and K management. In case of wheat, soil temperature was higher with the 6.0 t ha⁻¹ CR at 30 DAS (2.04, 1.52°C) compared to the observation taken at 60 DAS (1.44, 1.46°C) and at harvest (1.09, 1.07°C) in both years of wheat, respectively (Figure 1). In both residue and K management treatments lower soil temperatures were recorded at 60 DAS and later on it slightly increased at maturity to harvest stage in both years of wheat crop. Apparently not much difference was observed in soil temperature due to different K management practices in both maize and wheat crops at different growth stages. The fluctuation in soil temperature might be due to radiant, thermal and latent heat exchange which are the prime factors for soil temperature fluctuation. These factors are affected by many soil properties including soil structure and moisture content. The soil thermal properties influencing soil temperature are specific heat capacity, thermal conductivity, thermal diffusivity and albedo. The thermal conductivity of soil is more with less porosity and depends on their texture; sand > loam > clay > peat. In fixed soil structure, conductivity increases with water content (Buchan, 1991). Zhang *et al.*, (2009) stated that soil temperatures under mulch, were lowered during warmer season and increased during colder season as compared with non-mulched soil. Conversely during colder period, the input of solar energy is lower and there is less net loss of soil heat energy in to the atmosphere, resulting lesser temperature decrease in soil profile. The presence of residue mulch on soil surface insulate to loss of soil heat in to the atmosphere, indicating heat loss from the soil is somewhat lower under mulching than non-mulching, consequently soil temperature increased under mulch condition during winter season. Azooz *et al.*, (1995) observed

increased soil temperature in early season tilled seed bed compared to untilled areas. Soil temperature indirectly influenced plant growth through its impact on soil physical process *i.e.* rate of evaporation, rate of soil aeration and other chemical and biological process.

It may be concluded that crop residue retention at 4-6.0 t ha⁻¹ and application of 50% RDK+KSB have a positive residual impact on increasing summer greengram productivity by regulating soil temperature with favourable canopy temperature depression in maize and wheat under zero till maize-wheat-greengram cropping system.

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