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Research Article

Effect of Conservation Agriculture on Radiation Use Efficiency, Growth and Yield of Pigeonpea (*Cajanus cajan* L.)

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ABSTRACT

A study was carried out in the long term conservation agriculture experiments at the research farm of the IARI, New Delhi to evaluate the effect of various tillage practices on micrometeorological and yield of pigeonpea crop in pigeonpea-wheat cropping system. Pigeonpea crop was sown during *kharif* 2015. The field experiment was carried out with seven treatments i.e. conventional tillage (CT), permanent narrow-bed without residue (PNB), permanent narrow-bed with residue (PNB+R), permanent broad-bed without residue (PBB), permanent broad-bed with residue (PBB+R), zero tilled flat bed without residue (ZT), zero tilled flat bed with residue (ZT+R) arranged in a randomized block design (RBD) with three replications. Results showed that conservation practices had higher value of seed yield as compared to conventional practices. This may be due do more crop growth, higher radiation use efficiency, less crop stress, better soil condition and favourable crop micro environment during different crop growth stages in conservation practices as compared to the conventional practices.

Key words: Radiation use efficiency, leaf area index, biomass, yield, pigeonpea, conservation agriculture

Introduction

Conservation agriculture comprises three principles: reduced soil disturbance, maintaining soil cover with crop residues or green manures, and diversifying cropping systems (Sharma *et al*., 2012). It is promoted for its natural resource saving practice; maintain soil fertility, to fight against soil erosion, desertification and better use of scarce water resources. It also recognise due to its economic benefits, increase production, reduce production cost and labour reduction, increase farm income and better production stability, hence better food security. Huge quantities of crop residue are produced in cereal-cereal production systems. Large portion of unused crop residues are burnt in the fields with intention to clear the left-over straw and stubble for sowing of the succeeding crops. Total crop residue production in India is nearly 350 million tonnes of which one-third are available for recycling by soil incorporation or surface retention (Saad *et al*., 2016). Zero tillage (ZT) technique is an ecological approach for soil surface management and seed bed preparation resulting in less energy requirement, less weed problem, better crop residue management and higher or equal yield (Jain *et al*., 2007). The inclusion of legumes in crop rotation assumes a great significance to restore soil fertility. Pulses, next to cereals in terms of economic and nutritional importance have ability to biological nitrogen fixation, low water requirements, capacity to withstand drought, can contribute significantly to achieve twin objectives of increasing productivity and

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reduce need of nitrogen application as well cost of cultivation. Sinsinwar *et al*. (2003) observed that higher yield of cereal crops after legumes in rotation, which is mainly due to remnant effect of biological N fixation along with addition of legumes root biomass to succeeding wheat. Keeping these in mind, an experiment was conducted during *kharif* 2015 at the research farm of ICAR- Indian Agricultural research Institute, New Delhi to study the effect of conservation treatments along with conventional practice on crop growth parameters, radiation use efficiency and yield of pigeonpea in a pigeonpea-wheat cropping system.

Materials and Methods

Long-term conservation agriculture (CA) experiments were initiated in May 2010 at the research farm of the IARI, New Delhi on an alluvial sandy clay loam soil (fine loamy, illitic, Typic Haplustept). In *kharif* 2015, pigeonpea (*Cajanus cajan* L.) variety Pusa 992 was sown on 30th May in the pigeon pea-wheat cropping system. The field experiment was carried out with seven treatments i.e. conventional tillage (CT), permanent narrow-bed without residue (PNB), permanent narrow-bed with residue (PNB+R), permanent broad-bed without residue (PBB), permanent broad-bed with residue (PBB+R), zero tilled flat bed without residue (ZT), zero tilled flat bed with residue (ZT+R), in a randomized block design (RBD) with three replications.

Daily weather data during crop growing period were collected from the agro-meteorological observatory of the Division of Agricultural Physics, ICAR-IARI, New Delhi situated near the experimental plots. Observations on leaf area, biomass, plant height and chlorophyll content were recorded at different crop growth stages. Measurements of leaf area index were carried out at different growing stages using LAI-2000 Plant Canopy Analyzer (LI-COR, USA). For biomass, three plants were selected randomly from each plot and oven-dried at 65°C. Heights of three plants from each plot were measured by digital scale in the interval of 30 days during cropping season, and averaged. Leaf water potential was measured with the help of pressure bomb (PMS Instruments Co, USA). Seed yield were measured after harvest.

For calculating chlorophyll content, fresh leaf samples from different tillage treatments were taken; 100 mg sample was weighed accurately in an analytical balance, and chlorophyll from leaves was extracted by a non-macerated method equilibrating it with 10 ml dimethyl sulfoxide in a capped vial, and kept in an oven at 45°C overnight. The decanted solution was used to estimate the absorbance at 645 and 663 nm wavelength using Spectrophotometer Spectronic-20. Total chlorophyll content was calculated using the following formula:

Total chlorophyll content (mg/g of fresh weight) =

$$\frac{[20.2 \text{x} A_{645} + 8.02 A_{663}]V}{1000W} \quad \ldots(1)$$

where, A_{645} = Absorbance at 645 nm, A_{663} = Absorbance at 663 nm, V = Final volume of chlorophyll extract in DMSO and W= Weight of plant sample

For estimating relative water content (RWC), discs of 1cm diameter were taken from middle of fully developed leaves from each replicate under different treatments. Fresh weight was measured immediately, put into distilled water for around 5 h, and turgid weights were measured after drying excess surface water with paper towels. Dry weights (DW) were obtained after keeping at 75 °C for 48 h. The RWC was taken the ratio of difference between fresh and dry weights, and turgid and dry weights.

Both incoming and outgoing photo-synthetically active radiation (PAR) values were measured using line quantum sensor (LICOR-3000) at top of crop canopy, middle of crop height and bottom of crop throughout the crop growing season. To get reflected radiation from top and bottom ground, the sensor was held in inverse position. Measurements were taken in different growth stages between 11:30 and 12:00 h local time on clear days when disturbances due to leaf curling, leaf shading and solar angle were minimum. These data were further used to calculate radiation use efficiency (RUE): Amount of dry matter produced (g m^{-2})/ Amount of Cumulative light absorbed (MJ m^{-2})

Data were analyzed using SPSS (version 10.0), and MS Excel (version 7.0). Analysis of variance as applicable for randomized block design was used to test least significant differences among the various treatment means and their interactions using statistical analysis. MS Excel software package was used to draw the figures. The means of all the treatments were separated by DMRT at 5% level of significance and as per standard ANOVA. Pearson's correlation matrix was also computed.

Results and Discussion

Weather variability during kharif, 2015

Maximum temperature remained 0.2-7.6°C lower than the normal for thirty-two days and in rest of the growing period, temperature was higher than the normal by 0.2-4.1°C. Minimum temperature remained 0.1-4°C lower than the normal in sixty-eight days and it was 0.2-3.4°C higher than the normal in rest of the period. Total rainfall was 709.5 mm (against 512.1 mm as normal), while total rainy days were thirty-one. Maximum rainfall (161.9 mm) occurred on 12th July and the second highest rainfall was 65.2 mm (received on 11th July). Bright sunshine hours were observed 0.1-5.7 h lower than the normal in forty days and 0.1-4.5 h higher than the normal for remaining days. The soil evaporation was 0.6-5.8 mm leass than the normal in fifty-eight days; on rest of the days it was 0.1-3.2 mm higher than the normal. Wind speed was recorded 0.5-5.8 km h^{-1} higher than the normal except forty-two days (0.3-4.2 km h^{-1} lower than the normal). Maximum relative humidity at 7.21 morning was recorded higher than the normal throughout the crop growing period except thirty-six days that was 18-23% lower than normal. Minimum relative humidity was 1-37% higher during thirty days and for rests of the period, it was 2-30% higher than the normal (Fig. 1).

Leaf area index and biomass of pigeonpea

Maximum LAI was observed under PBB+R treatment (0.86) followed by PNB+R (0.82), ZT+R (0.78), PBB (0.76), PNB (0.72), ZT (0.70) and the minimum value was recorded in CT (0.66) at 35 DAS. Similar trend was observed at 70 and 105 DAS also. At 70 DAS, maximum LAI was

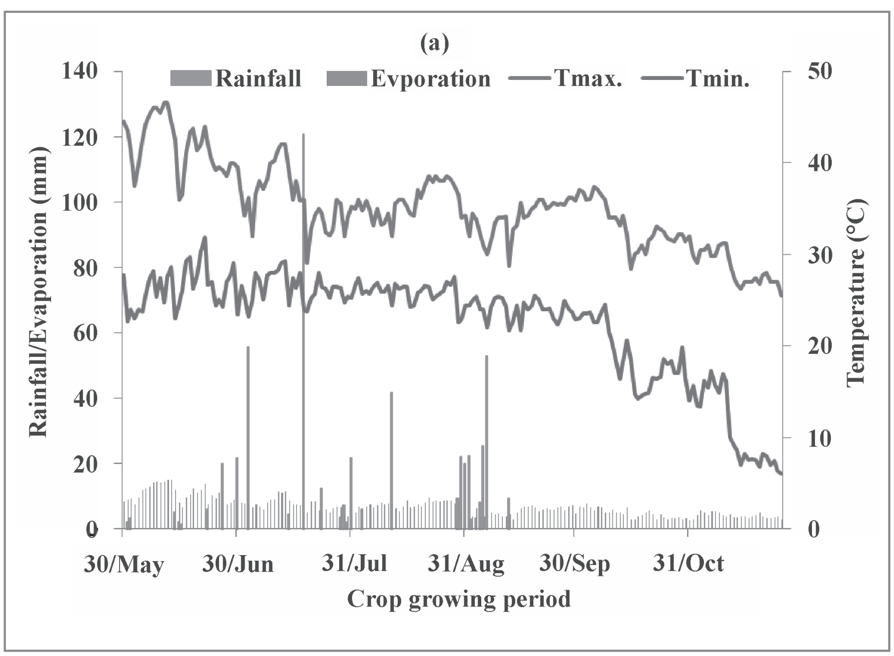

Fig. 1. Daily weather data during crop growing period *Kharif* 2015

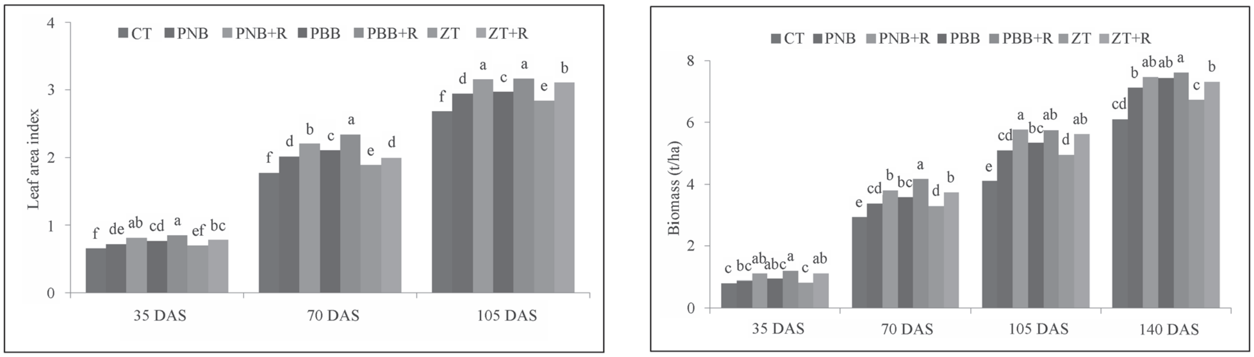

Fig. 2. Leaf area index and biomass under different conservation practices along with conventional practice in pigeonpea during crop growing season

recorded in PBB+R (2.48) which was significantly higher than rest of the treatments (ranging between 1.78 and 2.23). Maximum value of LAI was observed at 105 DAS in PBB+R treatment (3.17) followed by PNB+R (3.16); values were at par. Lowest LAI was observed in CT (2.69). LAI in treatments with residue retention (PNB+R, PBB+R and ZT+R) had higher values than those in treatments without residue (PNB, PBB and ZT) treatments (Fig. 2). Scopel *et al.* (2004) reported that increased quantity of surface residue was found to have a significant effect on plant available water, thus lowering the water stress and causing increase in leaf area index. Sangakkara *et al*. (2004) observed 21 and 10% increase in leaf area indices of cassava and sweet potato, respectively due to incorporation of legume leaf mulch.

Pigeonpea had accumulated biomass ranged between 0.8-1.2 t ha^{-1} at 35 DAS. Maximum biomass accumulation was found in PBB+R treatment (4.2 t ha^{-1}) at 70 DAS followed by PNB+R (3.8 t ha^{-1}), ZT+R (3.7 t ha^{-1}), PBB (3.6 t ha^{-1}), PNB (3.4 t ha^{-1}), ZT (3.3 t ha^{-1}) and CT (2.9 t ha^{-1}). Biomass in PBB+R was higher compared to other treatments. Maximum biomass was accumulated in PBB+R treatment (5.8 t ha^{-1}) at 105 DAS and lowest in CT treatment (4.1 t ha^{-1}). Conservation treatments had biomass accumulation ranged between 7.1-7.6 t ha^{-1} at 140 DAS (Fig. 2). CT and ZT had non-significant difference in biomass accumulation; other treatments (PBB+R, PNB+R, ZT+R, PBB, PNB, ZT) had significantly higher values over CT and ZT treatments. At harvest, biomass was maximum in PBB+R treatment (9.89 t ha^{-1}) followed by PNB+R (9.34 t ha^{-1}). These two treatments had similar biomass but higher than rest of the treatments. Meena *et al.* (2017) reported that conservation practices had higher value of leaf area index and biomass for wheat crop as compared to the corresponding value in conventional practices.

Khan and Pervej (2010) and Wang *et al*. (2011) indicated optimum soil temperature and soil moisture due to wheat straw mulches were the probable reason for increased in the dry matter accumulation in plant.

Plant height and chlorophyll content in pigeonpea

Plant height was measured at 35, 70, 105 and 140 DAS. Plant height increased rapidly in vegetative phase than the reproductive phase. Plant height at 30 DAS was highest in PBB+R treatment (61 cm) followed by PNB+R (59 cm), ZT+R (58 cm), PBB (55 cm), PNB(52 cm), ZT (50 cm) and CT (42 cm) treatment. At 70 DAS, PBB+R treatment had 124.7 cm plant height followed by 117 cm in PNB+R, 114 cm in ZT+R, 112 cm in PBB +R, 108 cm in PNB, 102 cm in ZT and 99 cm in CT treatment. Plant height at 105 DAS increased up to 135 cm to 169 cm in different treatments. Residue treatments (PBB+R, PNB+R and ZT+R) had higher plant height than other treatments throughout the growing period. Among conservation treatments, plant height was the maximum under PBB+R treatment and the minimum under ZT treatment. The CT showed lowest plant heights throughout the growing period. Plant height at 140 DAS increased up to 189 cm in PBB+R treatment, followed by PNB+R (181 cm), ZT+R (179 cm), PBB (175 cm), PNB (166 cm), ZT (163 cm) and CT (154 cm) treatment. The PBB+R treatment showed significantly higher plant height than the corresponding value in other treatments (Fig. 3).

Higher chlorophyll content was recorded in crop residue treatments. At 35 DAS, chlorophyll content was higher under PBB+R treatment (1.83 mg g^{-1}), followed by PNB+R (1.79 mg g^{-1}) and ZT+R (1.71 mg g^{-1}). In other conservation treatments it varied from 1.58 mg g^{-1} to 1.63 mg g^{-1} of fresh leaf weight. The least chlorophyll content was found under CT treatment (1.54 mg g^{-1}). At 70 DAS, PBB+R treatment had 2.17 mg g^{-1} chlorophyll content followed by PNB+R (2.12 mg g^{-1}), and in other treatments the same varied from 2.09 mg g^{-1} to 1.82 mg g^{-1}. At 105 DAS, it was increased up to 2.23 mg g^{-1} in PBB+R followed by PNB+R (2.20 mg g^{-1}), ZT+R (2.13 mg g^{-1}), PBB (2.05 mg g^{-1}), PNB (1.94 mg g^{-1}) and ZT (1.90 mg g^{-1}) treatment. The lower value of chlorophyll content was under CT treatment (1.87 mg g^{-1}). There were marginal differences among residue treatments (PBB+R, PNB+R, ZT+R) but these treatments had higher values than corresponding values in other treatments. The CT treatment had the lowest chlorophyll content (Fig. 3). Meena *et al.* (2017) reported that plant height and chlorophyll content had higher value in conservation practices for wheat crop as compared to the corresponding value in conventional practices.

Relative water content and leaf water potential in pigeonpea

The RWC was measured at 35, 70, 105 and 140 DAS. It gradually decreased from vegetative stage to physiological maturity. Maximum RWC was noted on 35 DAS and the lowest value was on 140 DAS. The values on 35 DAS varied between 87.5 to 76.4%. Highest value was under the PBB+R treatment (87.5%) followed by PNB+R (85.5%) and ZT+R (83.1%) treatment. On 70 DAS, RWC decreased from 85.2 to 74.5% under different treatments. On 105 DAS, it ranged between 80.4 to 70.3%, and on 140 DAS, highest values were obtained under the PBB+R treatment (77.8%) followed by PNB+R (76.09%), ZT+R (73.98%), PBB (73.38%), PNB (72.89%) and ZT (70.29%) treatment. Lowest value of RWC was found under CT treatment (70%) (Fig. 4). The PBB+R and PNB+R treatment had minor difference, but had significantly higher RWC than corresponding values in other treatments on 140 DAS.

Maximum leaf water potential (LWP) was recorded on 45 DAS, which was gradually decreased up to physiological maturity. Residue treatments had highest values of leaf water potential. On 45 DAS, PBB+R treatment had the highest value (-0.70 MPa) followed by PNB+R (-0.72 MPa) and ZT+R (-0.75 MPa) treatment. In other treatments LWP values varied from -0.82 to -0.86 MPa. The leaf water potential in PBB+R was -0.82 MPa followed by PNB (-0.83MPa), ZT (-0.85 MPa) and CT (-0.86 MPa) treatment. On 90 DAS, it gradually decreased as compared to that on 45 DAS. Maximum values of LWP was

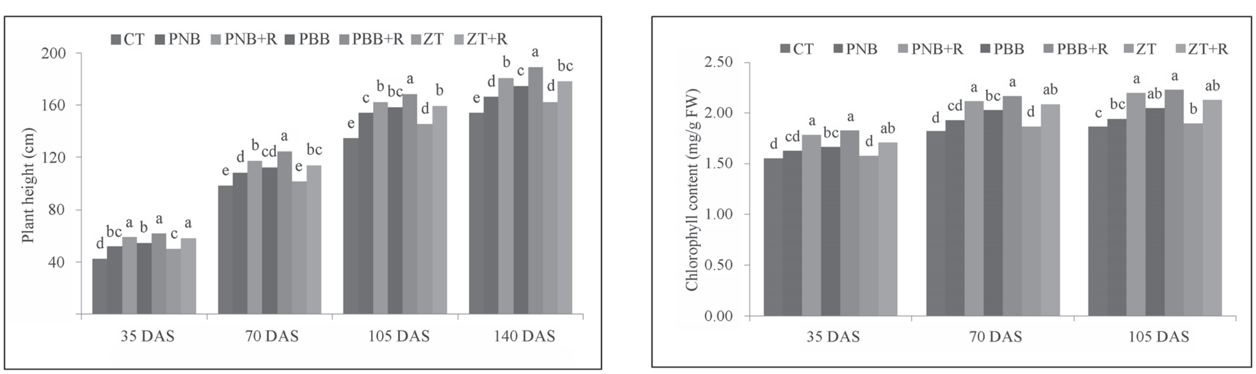

Fig. 3. Plant height and chlorophyll content under different conservation and conventional practices

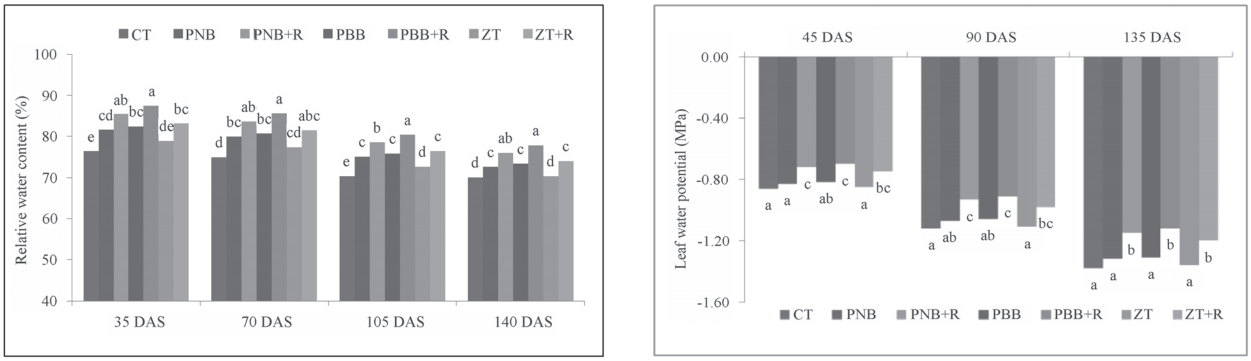

Fig. 4. Relative water content and leaf water potential in pigeonpea under different conservation practices

noted under PBB+R (-0.91MPa) followed by PNB+R (-0.93 MPa) and ZT+R (-0.98 MPa) treatment, and the lowest was under the CT treatment (-1.12 MPa). The LWP was found the lowest on 135 DAS, and decreased from -0.70 MPa (on 45 DAS) to -1.12 MPa (on 135 DAS) in PBB+R treatment. Other treatments had water potentials within -1.15 to -1.36 MPa. Residue treatments (PBB+R, PNB+R and ZT+R) had higher LWP values than the corresponding values in other treatments (Fig. 4). Meena *et al* (2017) reported that conservation practices had higher value of RWC and LWP for wheat crop as compared to conventional practices.

Radiation use efficiency in pigeonpea under conservation practices

On 35 DAS, the RUE was <1.0 g/MJ. On 70 DAS, It gradually increased and ranged between 1.14-1.39 g MJ^{-1} under different treatments. Residue treatments had higher RUE than other treatments. Maximum RUE ont 105 DAS was found under PBB+R treatment (1.62 g MJ^{-1}) followed by PNB+R (1.60 g MJ^{-1}) and ZT+R (1.54 g MJ^{-1}) treatment. Other conservation treatments had RUE between 1.36-1.50 g MJ^{-1}. Minimum RUE was found in CT treatment (1.28 g MJ^{-1}) (Fig. 5). Radiation use efficiency value at total dry matter (RUE_{TDM}) was ranged between 1.01 g MJ^{-1} to 1.22 g MJ^{-1}. CT (1.01 g MJ^{-1}) and PNB (1.07 g MJ^{-1}) treatment had non-significant difference for RUE_{TDM}. Maximum value of RUE_{TDM} was found under PBB+R treatment (1.22 g MJ^{-1}) followed by ZT+R (1.20 g MJ^{-1}) and PNB+R (1.18 g MJ^{-1}) treatment. These three treatments recorded similar RUE but had significantly higher values compared to other treatments. Bonhomme (2000) suggested that crop canopy could intercept 85% PAR only when crop had larger leaf area and this supported our

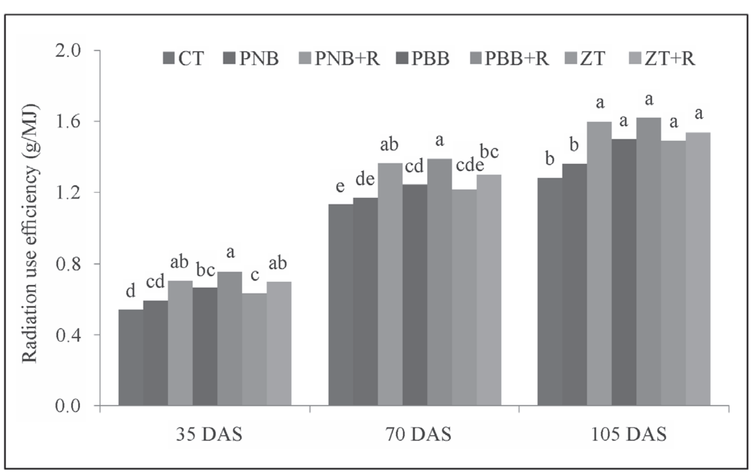

Fig. 5. Radiation use efficiency in pigeonpea under different conservation and conventional practices

Table 1. Relationship between cumulative intercepted photosynthetically active radiation and pigeonpea crop biomass in different conservation practices along with conventional practice

Treatment	Regression equation	R^2	p-value
CT	y=1.10x-134.9	0.90	0.005
PNB	y=1.23x- 163.7	0.89	0.003
PNB+R	y=1.49x-211.2	0.94	0.007
PBB	y=1.38x-198.7	0.91	0.001
PBB+R	y=1.56x-236.1	0.98	0.007
ZT	y=1.47x-215.7	0.92	0.010
ZT+R	y=1.50x-231.6	0.97	0.002

findings that less fIPAR were observed in treatments which had less leaf area in conventional treatment and zero tillage narrow bed treatment.

Linear regression equations were applied to develop the relationship between crop biomass and cumulative intercepted photosynthetically active radiation to estimate RUE. Slope gives a specific value of the increment by intercepting more units of PAR, which can evaluate the productivity of the crop. Slope for CT treatment had lowest value (1.10 g MJ^{-1}) with R^2 value of 0.90 ($p = 0.005$). Conservation treatments had higher slope than CT treatment indicates that they had higher RUE than CT treatment. Among conservation treatments, PBB+R had maximum slope 1.56 g MJ^{-1} with R^2 value 0.98 ($p = 0.007$) followed by ZT+R (1.50 g MJ^{-1}) with R^2 value 0.97 ($p = 0.0015$) (Table 1).

Yield and yield attributes of pigeonpea

Residue treatments (PBB+R, PNB+R and ZT+R) provided better microenvironment. These had better growth resulting in higher yield. The PBB+R had maximum yield (2211 kg ha^{-1}) followed by PNB+R (2072 kg ha^{-1}), ZT+R (2064 kg ha^{-1}), PBB (2035 kg ha^{-1}), PNB (2032 kg ha^{-1}) and ZT (1992 kg ha^{-1}) treatment (Table 2). Lowest yield was found in CT treatment (1816 kg ha^{-1}). 1000 seed weight ranged from 90.5 g to 82.7 g within different conservation treatments with the lowest weight was observed in CT (80.4 g) treatment. Number of pods per plant had maximum value of 164 in PBB+R treatment followed by PNB+R (154) and ZT+R (145) treatment. Yield, 1000 seed weight and number of pods per plant had higher values in PBB+R and PNB+R treatment as compared to corresponding value in other treatments. These two treatments had non-significance difference at 5% level of significance. Number of seeds/ 100 pods had maximum value of 407 under PBB+R treatment, and the lowest value under CT treatment (365). The CT and ZT treatments were at par. Due to favourable microenvironment conditions under CA treatments, yield was more than CT. Straw mulching was found to increase 100-seed weight and yield attributes (Wang *et al*., 2011). Meena *et al* (2017) reported that conservation practices had higher yield for wheat crop compared to conventional practices. Khan *et al*. (2009) who further revealed that in zero tillage crops produced higher grain yield in comparison to conventional and deep tillage crop.

Table 2. Yield and yield attributes in pigeonpea crop under conservation and conventional practices

Treatment	Seed yield (kg ha^{-1})	1000 seed weight (g)	No. of pods/ plant	No. of seeds/ 100 pods
CT	1816^{b}	80.4^{d}	116^{d}	365^{c}
PNB	2032^{ab}	82.7^{cd}	126^{d}	387^{ab}
PNB+R	2072^{ab}	87.3^{ab}	154^{ab}	395^{ab}
PBB	2035^{ab}	85.6^{bc}	137^{c}	390^{ab}
PBB+R	2211^{a}	90.5^{a}	164^{a}	407^{a}
ZT	1992^{ab}	80.5^{d}	119^{d}	377^{bc}
ZT+R	2064^{ab}	86.3^{bc}	145^{bc}	393^{ab}
LSD (0.05)	149	4.6	22	31

Conclusions

Among all the conservation treatments, higher yield was obtained in zero-tilled permanent broad bed plus residue (PBB+R) followed by zero tilled permanent narrow bed plus residue (PNB+ R), zero tilled flat bed plus residue (ZT+R), zero tillage broad bed (PBB), zero tilled permanent narrow bed (PNB), zero tillage flat bed (ZT), conventional practice (CT) system. Higher values of crop yield in conservation practices could be due do better crop growth and more favourable environment owing to better soil condition and crop micro environment. It can be concluded that conservation practices provide a new, multi-benefit tool for crop production. It provides favourable microenvironment for crop growth, increase crop production, hence give better food security at sustainable use of natural resources.

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