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EFFECT OF BALANCED FERTILIZATION IN PUDDLED RICE ON THE PRODUCTIVITY OF LENTIL IN RICE-FALLOW SYSTEM UNDER ZERO TILLAGE

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Abstract

Lentil (*Lens culinaris* Medik) predominantly grows under rainfed conditions under residual soil moisture in most of the rice-fallows in India with low productivity. Imbalanced NPK (N_1), recommended dose of NPK (N_2) and recommended NPK + 10 t ha^{-1} FYM (N_3) were applied in *kharif* rice (var. IET 4786) through consecutive three years (2011-2013). Two lentil varieties viz. Asha (B-77) and Subrata (WBL-58) were sown after rice under zero tillage conditions keeping standing residues and mulch through utilizing residual moisture and nutrients. Zero tillage with straw mulch (ZT-M) in both lentil varieties conserved 12-20% more water than residue removal (ZT) and 7-10% more than standing residue (ZT-H), respectively. During flowering (60 DAS) surface soil (0-5 cm) of ZT attained 0.8 MPa as compared to 0.2 and 0.1 MPa for ZT-H and ZT-M, respectively**.** Soils with N_3 stored more water and depleted lesser than N_2 and N_1 which produced higher biomass, leaf relative water content (RWC) and chlorophyll content. Soil thermal variation in ZT-M tends to proliferate root and nutrient uptake that increased 19 and 14% more yield and 25 and 15% more water use efficiency (WUE) than ZT-H and ZT. Both Subrata and Asha performed well under zero tillage conditions. Zero tillage and nutrient management had an effect on soil microbial biomass carbon (SMBC) and dehydrogenase activity as ZT < ZT-H < ZT-M and $N_3 > N_2 > N_1$. Proper technology with application of zero tillage may explore the possibility of growing lentil crops in rice fallows during post-rainy season utilizing carry-over soil moisture and residual soil fertility.

Introduction

Lentil is an annual, most promising cool season grain legume in India, ranks first in the world in respect of production, accounting for approximately 27% of the world's production with a national average productivity of 1000 kg ha^{-1} under rainfed conditions. In West Bengal, lentil occupies an area of 0.065 m ha area with a productivity of 763 kg ha^{-1} (FAO, 2010), grows under rainfed conditions on residual soil moisture during pre winter (from late November to early December) and faces soil moisture deficit and high temperature at reproductive growth stage (Gupta and Bhowmick, 2005). However, information on actual moisture needs and time and intensity of stress occurs using post-rainy season crops with residual soil moisture in rice fallows are very scarce. If ploughing is done after harvest of rice to remove stubbles, sowing of lentil is delayed which in turn produce water deficit conditions and that leads to abortion of flowers and young pods and prevents seed filling (Lal *et al*., 1988; Materne and Reddy, 2007). Nevertheless, all physiological processes in plants are directly affected by water availability (Sarker *et al*., 2005). The key objective is to tap residual soil moisture and leftover fertility of previous crop by the succeeding lentil crop. If balanced fertilization is done in rainfed puddled rice and crop residues are retained on the soil surface in combination with suitable planting techniques of lentil, it may alleviate terminal drought condition in crops by conserving soil moisture and bring overall improvement in resource management (Ghosh *et al*., 2010).

No till or zero tillage is an important component of conservation agriculture to produce crops at low cost with profound effect on natural resources such as water and soil (Gangwar *et al*., 2006). This system is very effective in minimizing soil and crop residue disturbance, controlling soil evaporation, minimizing erosion losses, sequestering carbon in soil and reducing energy needs (Kumar *et al*., 2011). Therefore, in the present study, the objective was to evaluate the effect of balanced fertilization in puddled rice on moisture storage, stress, microbial diversity and productivity of lentil in rice-fallow cultivated under zero tillage with residue management.

Materials and methods

Experimental site and treatments imposed

Field experiments were conducted in 2011-12 to 2013-14 in rice fallow area after short duration (120 days) *kharif* rice (var. IET 4786) with lentil (var. B-77, Asha and WBL-58, Subrata) under zero tillage in Nadia district of West Bengal (22.99˚N, 88.43˚E, 13 m msl). The climate is hot, humid subtropics with an average annual rainfall of approximately 1470 mm and mean annual minimum and maximum temperatures of 18 and 35 ºC, respectively. On average, 35 mm scattered rainfall occurs during November to March and 11 to 25 ºC temperatures (min. and max.) and 50-57% RH prevail at the pick growth period (Table 1). The soil is hyperthermic (Aeric Haplaquept, US Soil Taxonomy, Soil Survey Staff, 2003) and clay loam in texture (Table 2), neutral in pH, medium to high in bulk density with low organic matter contents. Three different nutrient managements were applied for rice- i) Farmers' practice (N_1, 40:20:20 as N: P_2O_5 K_2O), ii) Recommended dose of N:P_2O_5:K_2O = 80:40:40 (N_2) and iii) Recommended dose of N:P_2O_5:K_2O = 80:40:40 + 10 t ha^{-1} FYM (N_3), respectively. The rice crop was transplanted on 21st July with seedling age 21 days in rows and was harvested on 1st week of November in 2011, 2012 and 2013, respectively. Seven days after harvesting of rice, the land was used for lentil cultivation under zero tillage system. No fertilizer was applied for lentil, however, 2% DAP was sprayed at vegetative stage (30 days old). The experiment was laid out in factorial strip plot design with three residue management labels and three replications with the individual plot size being 5 m × 4 m. Three residue management under zero tillage assigned were:

(i) Zero tillage with residue removal (ZT): seeds were sown @ 30 kg ha^{-1} by drilling 65 mm with hand hoe in between two rice stubbles (6-8 cm height) of equal spacing.

(ii) Zero tillage with tall stubble residue (ZT-H): seeds were sown @ 30 kg ha^{-1} by drilling 65 mm with hand hoe in between two rice stubbles (20 cm height) of equal spacing.

(iii) Zero tillage with residue removal but straw mulching (ZT-M): seeds were sown @ 30 kg ha^{-1} by drilling 65 mm with hand hoe in between two rice stubbles (6-8 cm height) of equal spacing then application of surface straw mulch to cover the land.

Stubble cutting height of 6-8 and 20 cm stubble left 0.20 and 0.35 kg m^{-2} (~2.0 and 3.5 t ha^{-1}) residue that retained in the lentil field under ZT and ZT-H systems. On the other hand, 0.45 kg m^{-2} (~4.5 t ha^{-1}) rice straw mulch was applied (ZT-M) on 0.20 kg m^{-2} (~2.0 t ha^{-1}) residue left by normal cutting height (6-8 cm).

Table 1. Meteorological parameters during rice-lentil cropping system (pooled data of 2011-2012 to 2013-2014)

Month	Temperature (°C)		Rainfall (mm)	RH (%)	Evapo-transpiration rate (mm d^{-1})	Bright sunshine hour
	Max	Min				
July	32.7	26.4	198.7	79.6	2.4	4.8
August	32.0	26.2	388.2	81.5	2.1	4.3
September	32.8	25.9	268.5	77.7	2.2	5.0
October	32.6	23.5	112.8	66.7	2.2	6.8
November	29.8	17.3	9.4	55.7	1.5	7.3
December	25.9	12.5	2.4	58.4	1.0	5.9
January	24.2	11.1	2.5	57.4	1.1	5.6
February	28.8	12.7	9.5	50.3	1.5	6.2
March	32.8	17.5	10.9	47.1	2.7	8.2

Table 2. Physical properties of soil of the experimental soils

Soil Properties	Soil depth (cm)					
	0-5	5-10	10-20	20-30	30-40	40-60
Sand (%)	35	35	33	35	31	38
Silt (%)	28	28	29	27	27	26
Clay (%)	37	37	38	38	42	36
Textural class	Clay loam					
Bulk density (g cm^{-3})	1.42	1.51	1.60	1.65	1.70	1.73
WHC (%)	68	67	64	62	60	60
Saturated hydraulic conductivity (cm h^{-1})	0.12	0.12	0.07	0.03	0.01	0.01
Soil moisture content (%) at FC and WP	34, 15	34, 15	31, 12	28, 12	28, 12	28, 12

Soil moisture studies

Soil moisture measurement was done by using core sampler of 4 cm in diameter and a length of 3 cm for the surface soil (0-5 cm) and by a PR2/6 Profile Probe soil moisture meter for 5-10, 10-20, 20-30, 30-40 and 40-60 cm depths at 7 days interval in three years. The periodic stress coefficient K_s was determined as stated by Allen *et al*. (1998) using soil moisture depletion study. The actual water use (AWU) throughout the growing season of lentil was computed using the water balance relationship as:

$$\mathbf{AWU = D_r + P} \quad ...... \quad (1)$$

where, D_r = soil moisture depletion in the root zone (40 cm) from sowing to the end of the season (mm); P = effective precipitation in the crop growth season (mm), collected from the nearby meteorological observatory.

Plant parameters

The relative water content (RWC) of leaves was estimated at vegetative [30 days after sowing (DAS), flowering (60 DAS) and pod formation (90 DAS) stages by the method of Barrs and Weatherly (1962) by using the following equation:

$$RWC = \frac{FW - DW}{TW - DW} \times 100 \qquad ...... \qquad (2)$$

Where, TW = turgid weight, DW = dry weight and FW = fresh weight of leaves. Maximum above ground dry biomass was measured at vegetative, flowering and at pod formation stages.

Yield and water use efficiency

The lentil crops were harvested manually by uprooting at grain maturity stage (15% moisture content) on the second week of March. The water use efficiency (WUE, kg ha^{-1} mm^{-1}) was calculated using lentil seed yield in relation to actual water used from sowing to harvesting as:

$$WUE = \frac{\text{FLentil seedyield}}{\text{Total water used}} \qquad ...... \qquad (3)$$

All statistical analyses were performed using IBM, SPSS v. 20.0 (SPSS Inc. Chicago, IL, USA) for windows. Nutrients and residue effects on measured variables were performed by analysis of variance (ANOVA) through the general linear model (GLM) using factorial strip plot design.

Results and discussion

Soil moisture dynamics

Temporal soil moisture distribution throughout the profile indicated a decrease in trend from sowing to harvesting under different residues and nutrient management practices (Fig. 1). No significant variations of spatial and temporal moisture content were observed in plots with Asha (B-77) and Subrata (WBL-58). Results showed that treatments with ZT-M dried slower than ZT-H and ZT, respectively, however, no significant variations were observed under residual effect of nutrient management in rice. The rate of diminution soil moisture with time was more in surface (0-5 cm) soils of ZT compared to ZT-H and ZT-M (Fig. 1) indicating more evaporation loss as the exposed soil is venerable to evaporation (Kar and Kumar, 2009). During initiation of flowering the depletion was observed more in ZT and less in ZT-M; more in N_1 as compared to N_2 and N_3 treatments, however, no differences among Asha and Subrata in tillage and nutrients management was observed.

The distribution of moisture content of 1m profile with depth and time during the lentil growth period (Fig. 1) shows that at any suction value, the volumetric moisture retention is the lowest at the surface and is the highest at the bottom most layer of the soil profile. It was also evidenced that a hydraulic gradient existed upward in the root zone indicating an upward capillary flux might have occurred from deeper soil layers. However, a reduction in soil moisture at 20-30 cm layer forming neckline (Fig. 1), signifies mechanical impediment that might restricts upward contribution. The critical soil moisture, worked out from water availability decreased with increasing depth with a mean value of 22%.

At surface soil (0-5 cm), zero tillage with straw mulch (ZT-M) conserved 3-8% higher amount of moisture as compared to zero tillage with residue (ZT-H) or without (ZT) (data not shown). There was a sharp fall in soil moisture storage from vegetative to pod formation stages (Table 3). Zero tillage controls the stored soil moisture significantly at the trend of ZT-M > ZT-H > ZT. Residue with ZT-M and ZT-H stored 12-20% and 4-13% more water than ZT. Nonetheless, ZT-M stored 7-10% more than ZT-H, respectively. Favourable hydrothermal regime due to mulching encouraged root growth and thus enhanced utilization of conserved soil moisture by rainfed crops (Acharya and Sharma, 1994). Soil fertility levels also modified soil moisture storage significantly as $N_3 > N_2 > N_1$ where N_3 and N_2 stored 9-16% and 4-13% more moisture than N_1. Soils under variety Asha (B-77) stored significantly higher soil moisture (6-11%) as compared to Subrata (WBL-58). The actual water used by lentil crop in the root zone (0-40 cm) was significantly affected by zero tillage where ZT > ZT-H > ZT-M, amounting 19.5, 18.8 and 18.7 cm, respectively (Table 4). On average, 19.0 cm water was actually used by lentil crop under zero tillage systems. The finding is in close agreement with 18.5 cm (Tuti *et al*., 2012) in humid tropical and sub-tropical climate. Lower profile water change (depletion) under lentil in ZT-M was due to less or no evaporation from soil surface throughout the growing period as compared to ZT-H and ZT, respectively (Table 4). The lentil crop received 12.9 mm mean effective precipitation during the cropping seasons. An artificial barrier with straw and standing stubbles may help for slow and steady entry of water and thus may reduce drainage loss. Nutrient management in rice also significantly affected the actual water use as $N_1 > N_2 > N_3$ indicating the effect of continuous application of FYM on soil moisture dynamics.

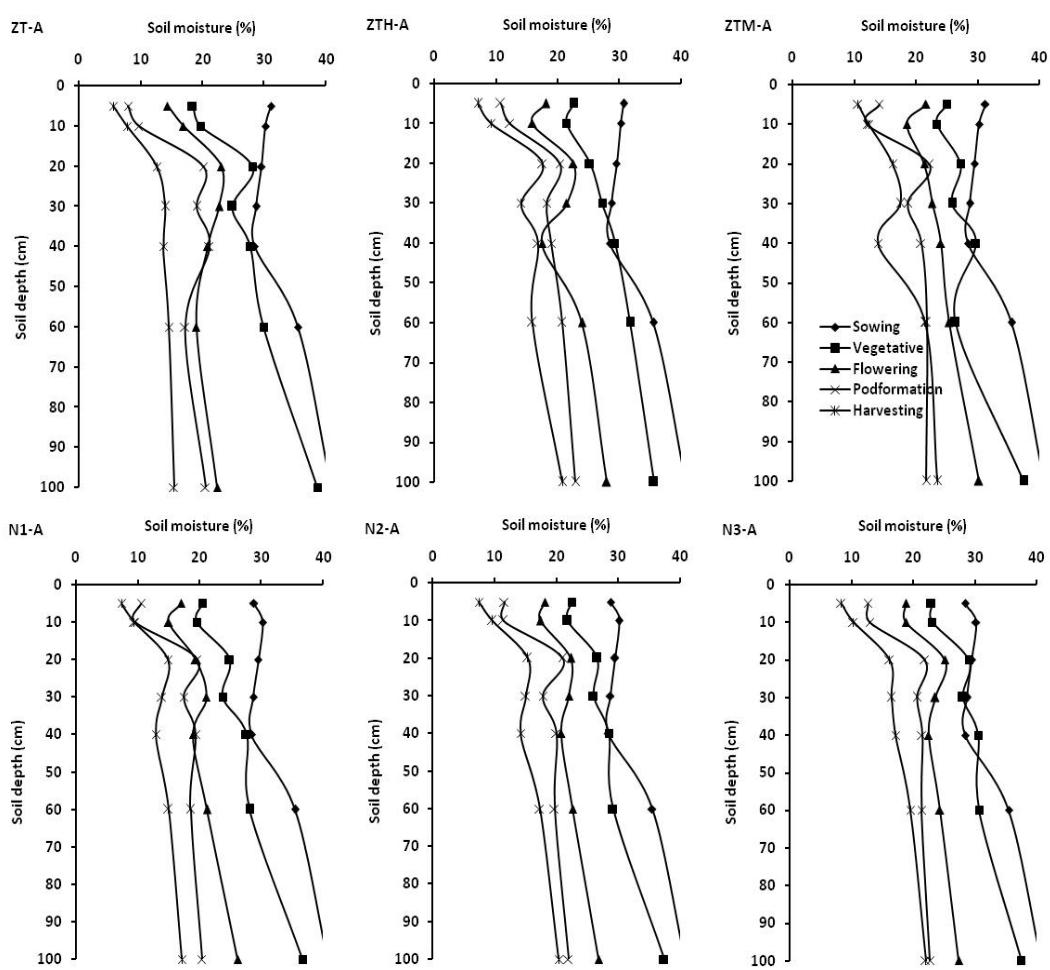

Fig. 1. Distribution of moisture within soil profile at critical growth periods under different nutrient and residue management practices (pooled data of three years with var. Asha)

Table 3. Soil moisture storage (cm) at critical stages under different nutrient and residue management practices

Residue	Asha			Subrata			Mean		
	V	F	Pf	V	F	Pf	V	F	Pf
ZT	8.79	7.43	5.78	8.12	6.68	4.65	8.46	7.05	5.21
ZT-H	9.50	7.61	6.28	8.38	7.02	5.72	8.94	7.32	6.00
ZT-M	9.70	8.11	6.69	9.53	8.06	6.40	9.61	8.08	6.54
Mean	9.33	7.72	6.25	8.68	7.25	5.59	9.00	7.48	5.92
Nutrient	V	F	Pf	V	F	Pf	V	F	Pf
N_1	8.83	7.08	5.91	8.21	6.36	5.38	8.52	6.72	5.64
N_2	9.23	7.76	6.15	8.49	7.40	5.63	8.86	7.58	5.89
N_3	9.93	8.31	6.69	9.33	8.00	5.76	9.63	8.16	6.23
Mean	9.33	7.72	6.25	8.68	7.25	5.59	9.00	7.48	5.92
Source	LSD (0.05)								
Nutrient	0.217								
Residue	0.238								
Variety	0.145								
Stage	0.258								
Residue*Var	1.234								

N_1 = 40:20:20 as $N:P_2O_5$: K_2O, N_2 = recommended $N:P_2O_5$: K_2O = 80:40:40, $N_3 = N_2$ + 10 t ha^{-1} FYM, FYM = Farmyard manure, ZT = Zero tillage with residue removal, ZT-H = Zero tillage with tall stubble height, ZT-M = Zero tillage with residue removal but with straw mulch, V= Vegetative stage, F= Flowering stage, Pf= Pod Formation stage.

Table 4. Total water used of lentils (cm) under different nutrient and residue management practices

Residue/ Tillage	Asha			Subrata			Mean		
	D (cm)	P (cm)	W (cm)	D (cm)	P (cm)	W (cm)	D (cm)	P (cm)	W (cm)
ZT	6.90	12.90	19.70	6.40	12.90	19.20	6.65	12.90	19.45
ZT-H	5.90	12.90	18.80	6.00	12.90	18.90	5.95	12.90	18.85
ZT-M	5.70	12.90	18.60	6.00	12.90	18.90	5.85	12.90	18.75
Mean	6.17	12.90	19.03	6.13	12.90	19.00	6.15	12.90	19.02
Nutrient	D (cm)	P (cm)	W (cm)	D (cm)	P (cm)	W (cm)	D (cm)	P (cm)	W (cm)
N_1	6.58	12.90	19.40	6.77	12.90	19.60	6.68	12.90	19.50
N_2	6.28	12.90	19.10	6.17	12.90	19.10	6.23	12.90	19.10
N_3	5.65	12.90	18.60	5.46	12.90	18.30	5.56	12.90	18.45
Mean	6.17	12.90	19.03	6.13	12.90	19.00	6.15	12.90	19.02
Source	LSD (0.05)								
Nutrient	0.277								
Residue	0.338								
Residue*Variety	3.086								

N_1 = 40:20:20 as $N:P_2O_5$: K_2O, N_2 = recommended $N:P_2O_5$: K_2O = 80:40:40, $N_3 = N_2$ + 10 t ha^{-1} FYM, FYM = Farmyard manure, ZT = Zero tillage with residue removal, ZT-H = Zero tillage with tall stubble height, ZT-M = Zero tillage with residue removal but with straw mulch, D= Depletion, P= Precipitation, W= Water used.

Plant growth parameters

Leaf relative water content (RWC) is of the best growth/biochemical indices revealing the stress intensity (Alizade, 2002). The RWC increased from vegetative to pod formation stages under all the treatments (Fig. 2). The RWC ranged from 62-65% during vegetative to 72-78% during flowering to 75-87% at pod formation stage for residue and nutrient management practices and it was significantly ($P < 0.05$) higher in ZT-H and ZT-M throughout the growth period as compared to ZT. At pod formation stage, ZT-H and ZT-M treatments significantly ($P < 0.05$) increased 12-15% higher RWC than ZT. On the other hand, RWC in N_3 and N_2 were 2-7% higher than N_1. Results thus indicated that where there were more moisture (plots with applied mulch and residue retention), the plants were turgid and succulent producing higher RWC compared to residue removal with low amount of moisture (Fig. 2). Both varieties had no significant effect on RWC at different growth periods.

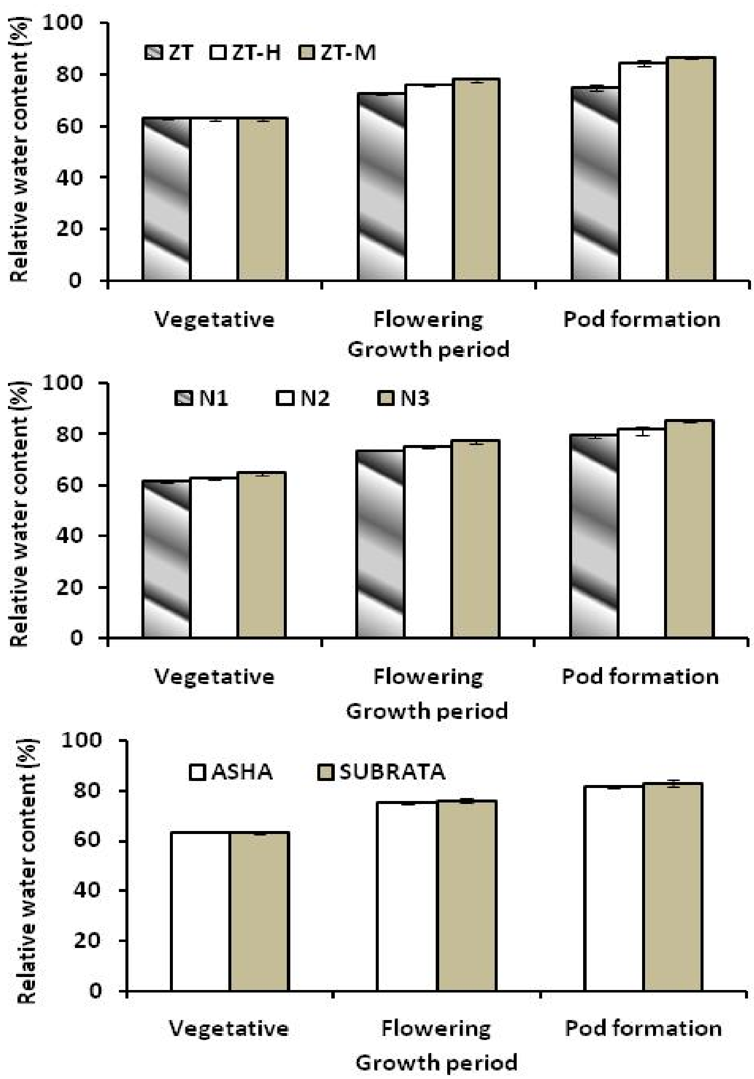

Fig. 2. Relative water content under different nutrient and residue management practices

Zero tillage with straw mulching had maximum dry biomass compared to ZT-H and ZT treatments at flowering and pod formation stages (Fig. 3). ZT-H and ZT-M produced 21 and 63% higher biomass as compared to ZT, and ZT-M produced 35% higher biomass than ZT-H. On the other hand, N_3 had 41% higher biomass than N_2 and 57% higher than N_1, respectively (Fig. 3). Asha (B-77) produced only 6% higher biomass than Subrata (WBL-58). Root:shoot ratio decreased with the advancement of crop growth (Fig. 4) indicating less root proliferation in zero tillage condition. ZT produced higher root-shoot compared to ZT-H and ZT-M may be due to increase of root system in cracks developed under moisture stress (Bandyopadhyay, 2014).

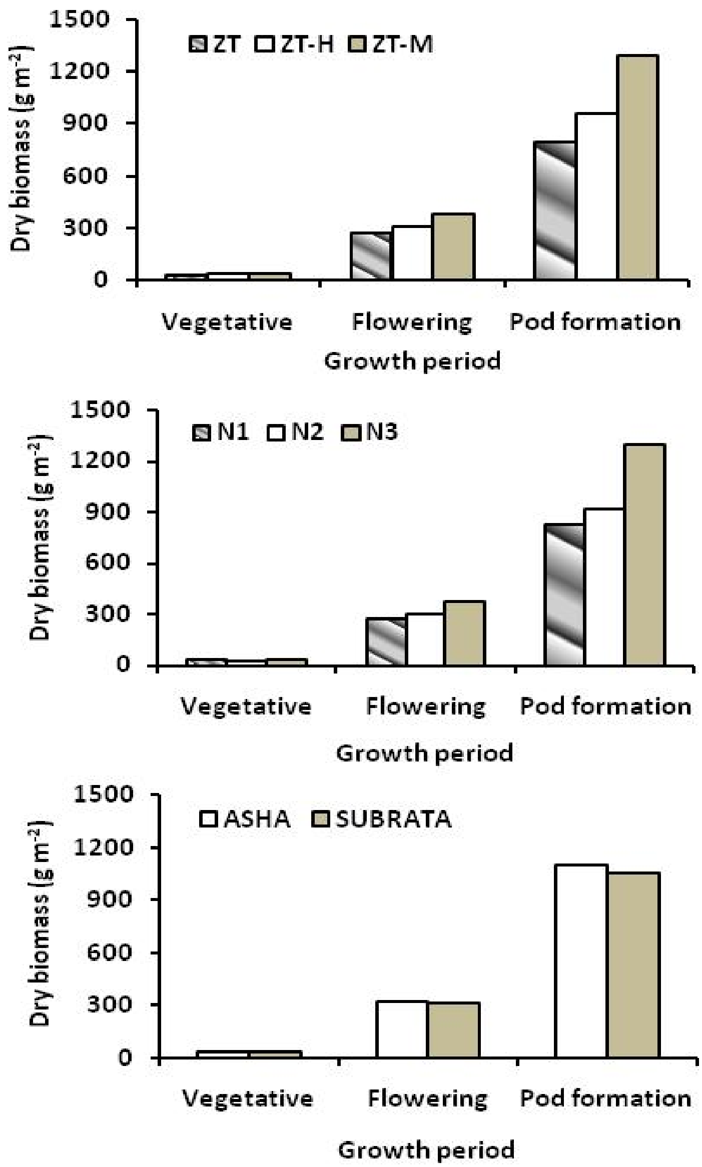

Fig. 3. Dry biomass under different nutrient and residue management practices

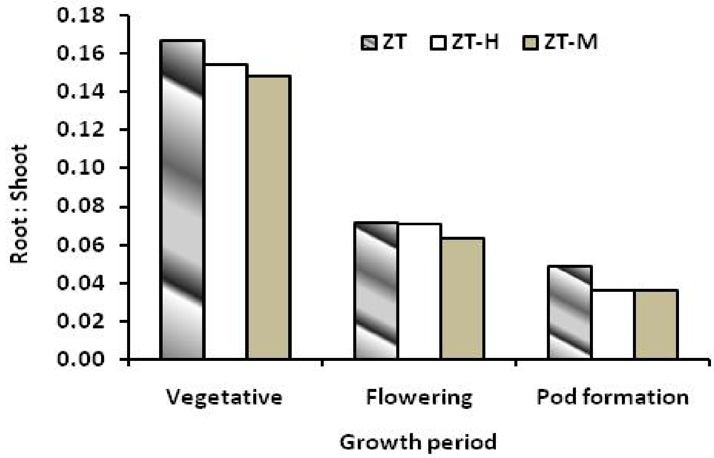

Fig. 4. Root: shoot ratio under different nutrient and residue management practices

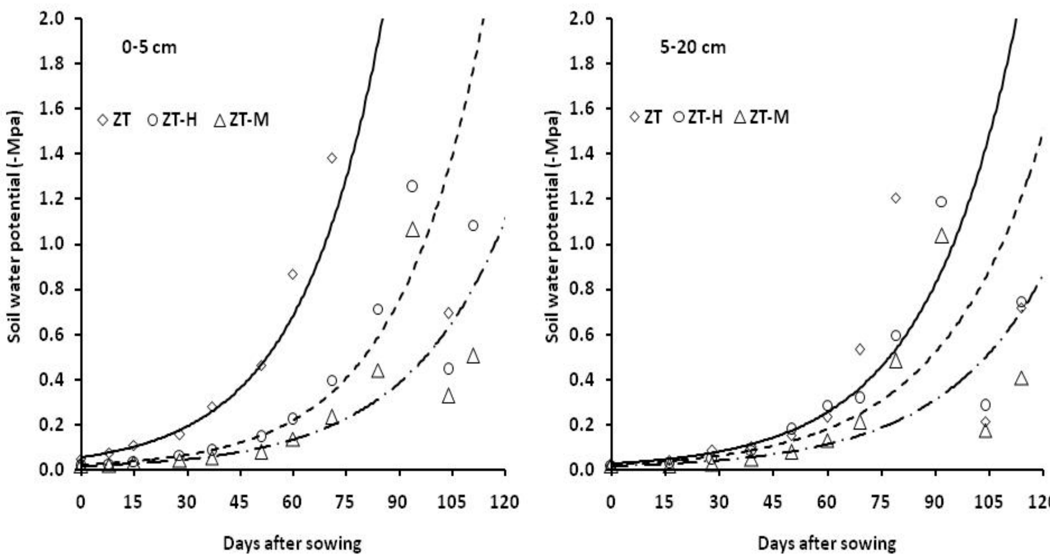

Fig. 5. Soil drying out pattern under zero tillage (ZT) with stubble height (ZT-H) and with mulch (ZT-M)

Soil Properties

Soil drying pattern of ZT-M was slower than ZT-H and ZT at surface (0-5 cm) and subsurface (5-20 cm) soil layers (Fig. 5) throughout the growth period. During initiation of flowering (60 DAS) ZT achieved 0.8 MPa tension as compared to 0.2 and 0.1 MPa for ZT-H and ZT-M, respectively. Results thus showed that the drying out pattern during flowering to pod formation stage may be modified by keeping straw mulching (ZT-M) or tall stubble height (ZT-H). The intensity of stress faced by lentil, under zero tillage is depicted in Fig. 6. At the beginning of the growing season (10 DAS), lentil in zero tillage showed the values of K_s = 1, i.e., the soil water deficit was less than the readily available water of the root zone. During flowering stage, lentil with residue removal (ZT) experienced more than 20% stress and it increased gradually. The diminution of K_s values may be attributed to the increase in water depletion at the root zone through the removal of water by evapotranspiration that induced stress condition (Bandyopadhyay and Mallick, 2003). The Ks values of the soil to 40 cm rooting depth reached below a value of 0.5 and 0.8 (Fig. 6) at pod formation stage (100 d) with ZT and ZT-H, however, stress starts in ZT-M after 105 d when the pod matured. A steep decrease with prolonged lower K_s values of ZT indicates a more stressed condition than ZT-H (Fig. 6). Thus, zero tillage reduced the intensity of stress. Zero tillage and nutrient management had an effect on soil microbial biomass carbon (SMBC) and soil dehydrogenase activity (Fig. 7). Mulch treatment (ZT-M) produced more SMBC and dehydrogenase as compared to residue removal (ZT) and low fertility (N_1). Asha (B-77) and Subrata (WBL-58) had no significant effect on SMBC and dehydrogenase activity.

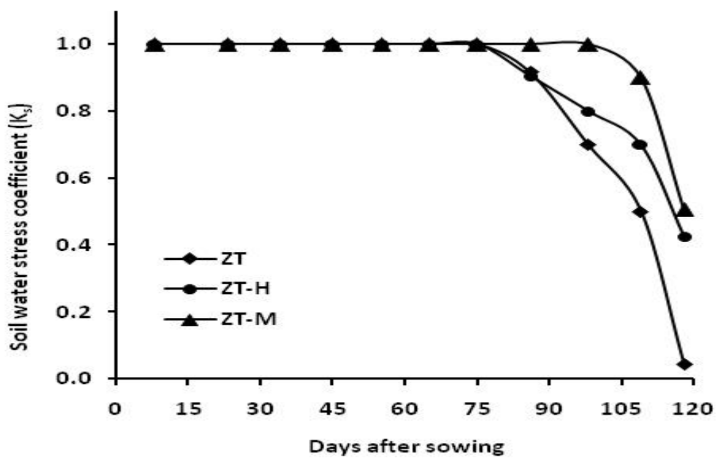

Fig. 6. Soil water stress coefficients under different residue management practices

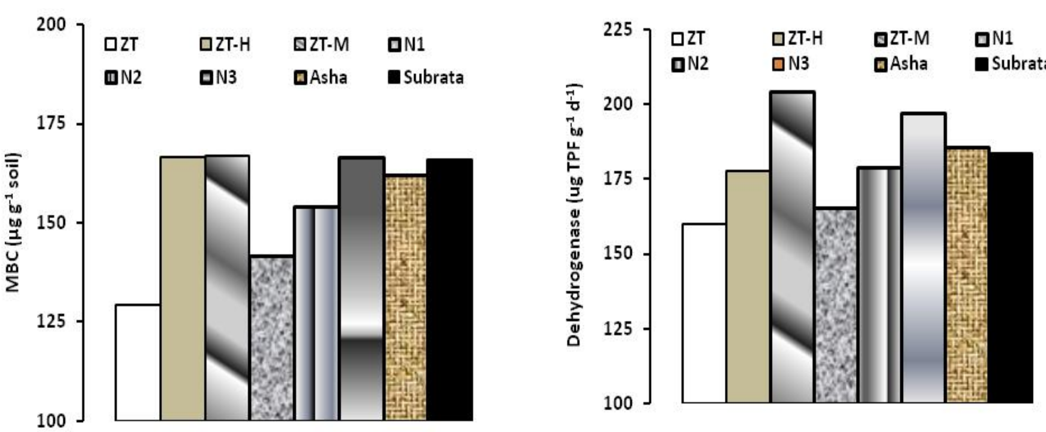

Fig. 7. Microbial biomass C and soil dehydrogenase activity under different nutrient and residue management practices

Yield and water use efficiency

Pooled data of yield for three years indicated that the yield was significantly affected by zero tillage and nutrient management as ZT-M > ZT-H > ZT and $N_3 > N_2 > N_1$ (Table 5). ZT-M (22.1 q ha^{-1}) produced 19.0 and 14.5% more yield than ZT (17.9 q ha^{-1}) ZT-H (18.9 q ha^{-1}). N_3 (20.9 q ha^{-1}) produced 7 to 11% more than N_2 and N_1, respectively. There was no significant variation in yield between variety (19.2 and 20.1 q ha^{-1}). Tripathi and Singh (1987), Singh and Verma (1996) in north India found the highest yield of 22.9 and 18.4 q ha^{-1} using different varieties. ZT-M significantly produced 15 and 25% higher water use efficiency (WUE) as compared to ZT-H (21.7 kg $ha^{-1}mm^{-1}$) and ZT (19.1 kg $ha^{-1}mm^{-1}$). Nutrient management with N_3 improved WUE @14 to 21% as compared to N_2 and N_1. The achieved WUE values of lentil in our study were within the range as described by Singh *et al*. (2010). Zero tillage with straw mulching modified soil temperature and kept minimal diurnal variation which tends to proliferate root and nutrient uptake that increased yield and WUE.

Table 5. Seed yield of lentil under different nutrient and residue management practices

Variety/ Treatment	N_1				N_2				N_3				Overall			
	ZT	ZT-H	ZT-M	Mean	ZT	ZT-H	ZT-M	Mean	ZT	ZT-H	ZT-M	Mean	ZT	ZT-H	ZT-M	Mean
Asha (B-77)	16.5	17.7	20.9	18.4	17.4	18.4	21.1	19.0	17.8	19.7	23.5	20.3	17.2	18.6	21.8	19.2
Subrata (WBL-58)	17.5	18.4	20.7	18.9	18.5	19.2	21.6	19.8	19.9	20.1	24.6	21.5	18.7	19.2	22.3	20.1
Mean	17.0	18.1	20.8	18.6	17.9	18.8	21.4	19.4	18.9	19.9	24.1	20.9	17.9	18.9	22.1	19.6
Source	LSD (0.05)															
Nutrient	1.20															
Residue	1.56															

N_1 = 40:20:20 as $N:P_2O_5: K_2O$, N_2 = recommended $N:P_2O_5: K_2O$ = 80:40:40, $N_3 = N_2$ + 10 t ha^{-1} FYM, FYM = Farmyard manure, ZT = Zero tillage with residue removal, ZT-H = Zero tillage with tall stubble height, ZT-M = Zero tillage with residue removal but with straw mulch.

Table 6. Water use efficiency as affected by different nutrient and residue management practices

Variety/ Treatment	N_1				N_2				N_3				Overall			
	ZT	ZT-H	ZT-M	Mean	ZT	ZT-H	ZT-M	Mean	ZT	ZT-H	ZT-M	Mean	ZT	ZT-H	ZT-M	Mea n
Asha (B-77)	16.1	19.6	23.2	19.6	18	20.6	24	20.9	19	23.6	30.2	24.3	17.7	21.3	25.8	21.6
Subrata (WBL-58)	17.2	19.6	22.3	19.7	20	23	23.8	22.3	24.1	24	29.7	25.9	20.4	22.2	25.3	22.6
Mean	16.7	19.6	22.8	19.7	19.0	21.8	23.9	21.6	21.6	23.8	30.0	25.1	19.1	21.7	25.5	22.1
Source	LSD (0.05)															
Nutrient	3.807															
Residue	2.239															

N_1 = 40:20:20 as $N:P_2O_5: K_2O$, N_2 = recommended $N:P_2O_5: K_2O$ = 80:40:40, $N_3 = N_2$ + 10 t ha^{-1} FYM, FYM = Farmyard manure, ZT = Zero tillage with residue removal, ZT-H = Zero tillage with tall stubble height, ZT-M = Zero tillage with residue removal but with straw mulch.

Conclusions

Zero tillage with straw mulch (ZT-M) in both lentil varieties conserved 12-20% more water than residue removal (ZT) and 7-10% more than standing residue (ZT-H), respectively. Depletion was more in residue removal (ZT), followed by standing residue (ZT-H) and mulch (ZT-M) that could influence soil drying through increasing soil stress and resistance. ZT-M and application of balanced fertilizer with FYM (N_3) produced higher biomass, RWC and improved soil microbial diversity. Mulch maintained soil temperature and water movement for growth and rooting in zero tillage system that produced 19 and 14% more yield and 25 and 15% more WUE than ZT-H and ZT, respectively. Zero tillage reduced the intensity of stress. Both lentil var. Asha (B-77) and Subrata (WBL-58) performed well under zero tillage system in this region. Balanced fertilization in rice cultivation and zero tillage with straw mulching or keeping tall stubbles height may be an efficient use of existing natural resources for mitigating soil moisture stress and could sustain lentil productivity above national average.

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