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Research Article

Study of Microclimate and Heat Use Efficiency of Happy Seeder Sown Wheat (*Triticum aestivum* L.) by using Rice Residue and Nitrogen Management Practices

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ABSTRACT

Field experiments were conducted at Punjab Agricultural University, Ludhiana during *rabi* 2016-17 and 2017-18 to assess the influence of different rice residue and nitrogen management practices on microclimate and heat utilization efficiency of happy seeder sown wheat. The experiment was conducted in randomized complete block design consisting of eleven residue and nitrogen management treatments in four replications. The results inferred that C + FYM_5 + N_{30+120} significantly improved PAR interception at all growth stages of wheat. Although soil and canopy temperature were not significantly affected, but presence of rice straw mulch in straw chopping treatments increased minimum and decreased maximum soil temperature and decreased canopy temperature. Crop with higher N application (150 kg/ ha) took significantly higher number of days to reach various phenophases as compared to treatments receiving lower N (125 kg/ha) at all stages except for days to crown root initiation. The cumulative GDD, HTU and PTU for attaining different developmental stages were highest in C + FYM_5 + N_{30+120} treatment. C + FYM_5 + N_{30+120} significantly improved heat use efficiency as compared to NC + N_{125},C+ N_{125} and C+FYM+ N_{125} treatments. The study concluded that rice residue in combination with nitrogen management practices could be used effectively to improve microclimate and heat use efficiency of happy seeder down wheat and to sustain its productivity under changing climatic scenarios.

Key words: Microclimate, Heat use efficiency, Happy seeder, Wheat, Rice straw, Nitrogen

Introduction

Wheat is one of the oldest and most important cereal crops of the world. It is India's prime most staple harvest, placed second only to rice. Recently, much attention is being paid to sowing of wheat under full residue retained conditions to alleviate the problems created by indiscriminate burning of paddy residues especially in north-west part of India. Reduced or no-till systems commonly leave all or part of the residues from the previous crop on the soil surface, which influences heat and water balance of the soil profiles over a growing season (Gupta *et al.,* 1981). Residue mulch kept on the soil modifies crop microclimate above and below soil surface Rani *et al*., 2017; Goel *et al*., 2020). Residue present on soil surface acts as a physical barrier for exchange processes on the surface of the soil, which changes the roughness of the soil/ atmosphere boundary layer, as well as the dynamical thermal and moisture properties of the surface layer (Kingra and Kaur, 2017; Kaur *et al*., 2019).

Kingra *et al*. (2019) reported that improved cultivation systems like zero tillage, bed planting

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and conventional tillage with mulch produce higher grain yield and improve water productivity of wheat than conventional planting. Irrigation management and retaining crop residue in field are other measures to manage terminal heat stress and improve water productivity in wheat. Rani *et al*. (2019) stated that the adoption of soil conservation practices is considered as the tools for improving soil properties for mitigation of adverse climate change, conservation of natural resources like soil, water and nutrients, while achieving environmental, social and economic benefits. Mulch is used to manage and manipulate radiation, heat, moisture and mechanical impacts in various forms by influencing exchange processes, most often positively, as well as by mitigating hazardous phenomena due to these processes (Stigter *et al.,* 2018). Bag *et al*. (2019) also reported increase in profile moisture storage with crop residue mulching. Thus, manipulating residue is a mean of altering the microclimate in agricultural production systems.

Temperature is the most critical weather parameter which determines the growth and productivity of wheat crop. Phenological development of any crop from sowing to maturity is related to accumulation of heat or temperature units above base temperature below which no growth takes place. The growing degree day (GDD) is a simple tool to find out the relationship between plant growth, maturity and mean air temperature. A degree day or a heat unit is the departure from the mean daily temperature above the minimum threshold temperature. The occurrence of different phenological events during crop growth period in relation to temperature can be estimated by using accumulated heat units or growing degree days (GDD) (Gouri *et al.* 2005), which can provide useful information about the occurrence of various crop developmental stages and harvesting date.

Although extensive research work has been already carried out on microclimate and heat unit requirement of wheat sown after conventional tillage, but knowledge on these aspects in respect of happy seeder sown wheat (rice residue retained on soil surface) is very limited. As the area under happy seeder sown wheat is increasing rapidly in the region, thus its microclimate and heat use efficiency needs to be evaluated so that practices for improving microclimate and enhancing heat use efficiency can be identified to manage the impacts of changing climatic scenarios on crop growth and productivity. Keeping this in view, the present study was undertaken to evaluate microclimate and heat use efficiency of wheat under residue retained conditions as influenced by different residue and nitrogen management practices.

Materials and Methods

Experimental details

The field experiment was conducted during *rabi* 2016-17 and 2017-18 in Punjab Agricultural University, Ludhiana, at latitude of 30°54′ N, longitude of 75°48′ E and altitude of 247 m above mean sea level. The soil of the experimental field was loamy sand in texture with normal pH (7.4), low in organic carbon (0.28 %), available N (195.3 kg/ha), medium in available P (23.1 kg/ha) and high in available K (217.8 kg/ha). Total rainfall received in wheat season was 100.2 and 86.4 mm in 2016-17 and 2017-18, respectively. The experiment was laid out in randomized block design with four replications having 11 treatments combinations as following:

i. NC+ N_{125} - No chopping of paddy straw and 125 kg N/ha

ii. C+ N_{125} - Chopping of paddy straw and 125 kg N/ha

iii. C+ FYM_5+ N_{125} - Chopping of paddy straw + FYM 5 t/ha + 125 kg N/ha

iv. C + N_{20+105} - Chopping of paddy straw + 20 kg N/ha at chopping of straw and 105 kg N/ha afterwards as recommended

v. C + N_{30+95} - Chopping of paddy straw + 30 kg N/ha at chopping of straw and 95 kg N/ha afterwards as recommended

vi. C + N_{20+130} - Chopping of paddy straw + 20 kg N/ha at chopping of straw and 130 kg N/ha afterwards as recommended

vii. $C + N_{30+120}$ - Chopping of paddy straw + 30 kg N/ha at chopping of straw and 120 kg N/ha afterwards as recommended

viii. $C + FYM_5 + N_{20+105}$ - Chopping of paddy straw + FYM 5 t/ha + 20 kg N/ha at chopping of straw and 105 kg N/ha afterwards as recommended

ix. $C + FYM_5 + N_{30+95}$ - Chopping of paddy straw + FYM 5 t/ha + 30 kg N/ha at chopping of straw and 95 kg N/ha afterwards as recommended

x. $C + FYM_5 + N_{20+130}$ - Chopping of paddy straw + FYM 5 t/ha + 20 kg N/ha at chopping of straw and 130 kg N/ha afterwards as recommended

xi. $C + FYM_5 + N_{30+120}$ -Chopping of paddy straw + FYM 5 t/ha + 30 kg N/ha at chopping of straw and 120 kg N/ha afterwards as recommended).

Paddy straw after combine harvesting of preceding rice was chopped by paddy straw chopper cum spreader into small pieces and a pre-sowing irrigation was applied to the field. FYM was applied on fresh weight basis immediately after chopping of straw. The loose chopped paddy straw was uniformly spread across the field to facilitate sowing with happy seeder. Gramoxone 24 SL (paraquat) @ 1.25 litre/ha in 200 litres of water was sprayed before sowing to control grassy as well as broad leaf weeds. Wheat variety PBW 677 was sown using a seed rate of 100 kg/ha on 15 November during 2016 and on 12 November during 2017 with turbo happy seeder with full residue retention at row spacing of 20 cm. Nitrogen was applied as per treatments. Phosphorus (62.5 kg P_2O_5/ha) and potassium (30 kg K_2O/ha) were applied as per PAU recommendations and whole quantity was applied at the time of sowing. Wheat was harvested on April 18 and April 15 during 2017 and 2018, respectively.

Observations recorded

Eight important crop phenological stages (crown root initiation, maximum tillering, 50 per cent booting, 50 per cent heading, anthesis, milking, dough and maturity) were recorded from five randomly selected tagged plants per plot. Grain yield was recorded as per the standard procedure. The whole plots were harvested (leaving one border row on each side and 0.5 m from each side of the length) and sun-dried for five days in the field and then the total biomass yield was recorded. After threshing, cleaning and drying, the grain yield (t/ha) was recorded and reported at 14 per cent moisture content.

Photo-synthetically active radiation (PAR) interception was measured by Line quantum sensor (LI-COR photometer model LI-191-SA) which has quantum (photon) response through wavelength range of 400-700 nm for photosynthetic photon flux density (PPFD) was used for PAR (μ mole $m^{-2}s^{-1}$) measurements. The interception of PAR by crop was calculated as:

$$\text{PAR interception (\%)} = \frac{\text{PAR (I)} - \text{PAR (T)} - \text{PAR (R)}}{\text{PAR (I)}} \times 100$$

Where,

PAR (I) - PAR incident above the canopy

PAR (T) - PAR transmitted to the ground

PAR (R) - PAR reflected

Soil temperature was measured using mercury-in-glass thermometer installed at 5 cm depth at 7:30 am (minimum) and 2.30 pm (maximum) periodically. Canopy temperature was recorded with the help of infrared thermo meter (DT 520) periodically at 2.30 p.m. from development of canopy till harvesting during the days with clear sky.

Computation of agroclimatic indices

Growing degree days (GDD) were calculated as per Nuttonson (1955).

$$\text{GDD (°C days)} = \sum_{i=1}^{n} \left(\frac{\text{Maximum temperature} + \text{Minimum temperature}}{2} \right) - \text{Base temperature}$$

Base temperature was taken as 4.5°C for wheat, which is the temperature below which no crop growth occurs.

Helio thermal units were calculated by using the formula given below:

$$\text{HTU}\,(^\circ\text{C day hour}) = \sum_{i=1}^{n} (\text{GDD} \times \text{Actual sunshine hours})$$

The formula used for calculating photo thermal units is given as:

$$\text{PTU}\,(^\circ\text{C day hour}) = \sum_{i=1}^{n} (\text{GDD} \times \text{Day length})$$

Heat use efficiency was calculated as following:

$$\text{HUE}\left(\frac{\text{kg}}{^\circ\text{C days}}\right) = \frac{\text{Grain yield}}{\text{GDD (to maturity)}}$$

Helio thermal use efficiency was calculated as following:

$$\text{HTUE}\left(\frac{\text{kg}}{^\circ\text{C days hour}}\right) = \frac{\text{Grain yield}}{\text{HTU (to maturity)}}$$

Photo thermal use efficiency was calculated as following:

$$\text{PTUE}\left(\frac{\text{kg}}{^\circ\text{C days hour}}\right) = \frac{\text{Grain yield}}{\text{PTU (to maturity)}}$$

Statistical analysis

Statistical analysis was performed using randomized block design as per procedure given by Cochran and Cox (1967). All the comparisons were made at 5 per cent level of significance. Pooled means were calculated by keeping year as main plot factor and treatments as sub plot factor using factorial RBD design.

Results and Discussion

Photo-synthetically active radiation (PAR) interception

The data revealed that PAR interception was significantly higher in chopping of paddy straw + FYM 5 t/ha + 30 kg N/ha at chopping of straw and 120 kg N/ha afterwards as recommended (C + FYM_5 + N_{30+120}) at 60, 90, 120 DAS and at harvest. However, it was statistically at par with C + N_{20+130}, C + N_{30+120}, C + FYM_5 + N_{20+105}, C + FYM_5 + N_{30+95} and C + FYM_5 + N_{20+130} treatments but significantly better than all other treatments (Table 1). PAR interception was also more in chopped straw treatments due to presence of straw mulch on soil surface as mulch favours better crop growth and higher leaf area index. Dadhwal (2011) and Kaur (2015) also reported more PAR interception where mulch was applied to crop.

Soil temperature

Seed germination, crop growth and development, availability of nutrients and water

Table 1. PAR interception of happy seeder sown wheat as affected by different residue and nitrogen management practices (Data pooled over two years, 2016-17 and 2017-18)

Treatments	PAR interception (%)			
	60 DAS	90 DAS	120 DAS	Harvest
NC + N_{125}	56.2	73.8	66.1	60.6
C + N_{125}	57.3	75.0	67.3	61.7
C + FYM_5 + N_{125}	57.7	76.2	68.8	63.4
C + N_{20+105}	59.6	78.4	70.2	65.3
C + N_{30+95}	61.2	79.2	71.3	66.1
C + N_{20+130}	64.1	82.0	74.0	68.0
C + N_{30+120}	64.8	83.5	75.7	69.5
C + FYM_5 + N_{20+105}	63.2	80.0	73.0	66.9
C + FYM_5 + N_{30+95}	64.5	83.1	74.7	68.8
C + FYM_5 + N_{20+130}	65.9	84.3	76.4	70.6
C + FYM_5 + N_{30+120}	67.1	85.4	77.5	72.2
CD (p=0.05)	5.0	5.2	4.9	6.0

and soil evaporation are greatly influenced by soil temperature during different stages of crop growth. Although different residue and nitrogen management practices did not have significant effect on soil temperature, however, numerical differences were recorded. Presence of straw mulch in chopped straw treatments increased minimum soil temperature by 1.1-1.6 and 0.8-1.0°C at sowing and 30 DAS, respectively. Maximum soil temperature was reduced in the presence of straw mulch to the tune of 2.6-3.0 and 2.2-2.9°C at sowing and 30 DAS, respectively (Table 2). At 60, 90 and 120 DAS, only maximum soil temperature decreased in chopped straw treatments due to presence of straw mulch although reduction was not much. Increase in minimum soil temperature might be due to decreased loss of radiation from soil surface due to the barrier effect of mulch, whereas decrease in maximum soil temperature might be due to less penetration of solar radiation to soil surface. Sidhu *et al.* (2007) and Kaur (2015) also reported increase in minimum temperature and decline in maximum soil temperature due to presence of straw mulch.

Canopy temperature

Lower canopy temperature was observed in chopped straw treatments as presence of straw mulch might have resulted in better crop growth and leaf area index, thus lowering canopy temperature. Straw mulch keeps canopy temperature lower during grain filling stage (cooling due to transpiration) owing to sustained soil moisture availability to the plants for reasons enumerated previously facilitating in better grain filling (Table 3). In absence of residue retention, farmers have no option but to match last irrigation with grain filling if terminal heat stress penalty is to be avoided. The lower canopy temperature in wheat sown with happy seeder in chopped paddy straw helps in minimizing the adverse effect of terminal heat on wheat grain yield. Gupta *et al.* (2010) and Jat (2017) also reported lower canopy temperature in happy seeder sown wheat due to the presence of straw mulch.

Crop phenology

Different residue and nitrogen management practices had significant effect on phenology of happy seeder sown wheat (Table 4). Crop under high N treatments (150 kg ha^{-1}) took more number of days to reach various phenophases as compared to treatments receiving 125 kg N ha^{-1} with significant difference at all stages except for days to crown root initiation. Treatment C + FYM$_5$ + N$_{30+120}$ took 147.7 days to reach physiological maturity, Whereas NC + N$_{125}$ took 144.6 days.

Table 2. Soil temperature of happy seeder sown wheat as affected by different residue and nitrogen management practices (Data pooled over two years, 2016-17 and 2017-18)

Treatments	Soil temperature (°C)						
	Sowing		30 DAS		60 DAS	90 DAS	120 DAS
	Min.	Max.	Min.	Max.	Max.	Max.	Max.
NC + N$_{125}$	16.0	26.3	14.3	20.7	17.9	24.4	29.7
C + N$_{125}$	17.1	23.7	15.3	17.8	15.4	22.0	27.4
C + FYM$_5$ + N$_{125}$	17.3	23.7	15.2	18.0	15.1	22.1	27.6
C + N$_{20+105}$	17.1	23.6	15.1	18.1	15.4	22.0	27.3
C + N$_{30+95}$	17.2	23.7	15.2	18.0	15.5	22.2	27.5
C + N$_{20+130}$	17.1	23.7	15.2	18.2	15.5	22.2	27.8
C + N$_{30+120}$	17.3	23.4	15.3	18.3	15.4	21.9	27.7
C + FYM$_5$ + N$_{20+105}$	17.5	23.3	15.4	18.4	15.6	22.0	27.5
C + FYM$_5$ + N$_{30+95}$	17.6	23.4	15.4	18.0	15.3	22.1	27.6
C + FYM$_5$ + N$_{20+130}$	17.5	23.5	15.2	18.5	15.4	21.7	27.2
C + FYM$_5$ + N$_{30+12}$	17.4	23.4	15.3	18.3	15.5	21.5	29.8
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS

Table 3. Canopy temperature of happy seeder sown wheat as affected by different residue and nitrogen management practices (Data pooled over two years, 2016-17 and 2017-18)

Treatments	Canopy Temperature (°C)				
	30 DAS	60 DAS	90 DAS	120 DAS	Harvest
NC + N_{125}	22.4	18.5	19.8	22.8	35.2
C + N_{125}	21.6	17.8	19.1	22.3	33.9
C + FYM_5 + N_{125}	21.7	18.2	19.3	22.2	34.0
C + N_{20+105}	21.5	18.0	18.7	22.5	33.2
C + N_{30+95}	21.6	18.3	18.4	22.6	33.9
C + N_{20+130}	21.6	18.2	18.7	22.4	33.6
C + N_{30+120}	21.4	18.3	18.6	22.5	33.3
C + FYM_5 + N_{20+105}	21.7	18.4	18.8	22.9	33.2
C + FYM_5 + N_{30+95}	21.3	18.2	18.7	22.8	33.2
C + FYM_5 + N_{20+130}	21.0	17.9	18.8	22.6	33.2
C + FYM_5 + N_{30+120}	21.1	17.7	18.4	22.3	33.1
CD (p=0.05)	NS	NS	NS	NS	NS

Table 4. Phenology of happy seeder sown wheat as affected by different residue and nitrogen management practices (Data pooled over two years, 2016-17 and 2017-18)

Treatments	Days taken to							
	CRI	Maximum tillering	50 per cent booting	50 per cent heading	Anthesis	Milking	Dough	Maturity
NC + N_{125}	22.8	56.1	77.6	91.6	103.1	121.2	135.2	144.6
C + N_{125}	23.0	56.4	78.1	92.5	104.5	121.8	136.1	145.1
C + FYM_5 + N_{125}	24.1	57.2	79.2	93.1	104.7	122.1	137.4	146.1
C + N_{20+105}	22.8	56.5	79.4	94.2	103.1	122.6	135.5	145.5
C + N_{30+95}	22.8	56.2	79.5	94.5	103.5	122.1	136.6	145.1
C + N_{20+130}	24.0	58.7	83.0	97.4	108.6	125.6	137.9	146.6
C + N_{30+120}	24.2	58.1	82.6	97.0	108.2	124.7	138.8	146.9
C + FYM_5 + N_{20+105}	22.9	56.6	79.6	95.1	104.9	122.6	138.2	145.6
C + FYM_5 + N_{30+95}	23.6	57.5	79.3	96.1	104.1	122.0	138.0	145.4
C + FYM_5 + N_{20+130}	24.0	58.4	83.1	98.2	108.5	125.6	139.7	147.5
C + FYM_5 + N_{30+120}	24.2	58.6	83.6	99.6	109.7	126.8	140.1	147.7
CD (p=0.05)	NS	0.6	0.5	0.8	0.7	1.1	0.9	1.5

Extended vegetative growth period under higher N application resulted in delayed physiological maturity. Several studies have shown that high N doses delay various phenophases in wheat (Singh *et al.,* 2011; Kaur, 2017).

Growing Degree Days (GDD)

The crop in treatment C + FYM_5 + N_{30+120} consumed higher heat units to attain all phenophases as compared to all other treatments (Table 5). The crop in this treatment took 1850.2°C days to attain physiological maturity, while crop in treatment NC + N_{125} took 1780.0 °C days for the same. Higher GDD accumulation under higher N application was due to higher number of days taken to reach different phenophases, which might be attributed to more vegetative growth due to more N. Presence of straw mulch in chopped straw treatments also resulted in higher cumulative GDD as compared to unchopped treatments.

Table 5. Growing degree days of happy seeder sown wheat as affected by different residue and nitrogen management practices (Data pooled over two years, 2016-17 and 2017-18)

Treatments	Growing degree days (°C days)							
	CRI	Maximum tillering	50 per cent booting	50 per cent heading	Anthesis	Milking	Dough	Maturity
NC + N_{125}	309.5	618.5	795.0	933.5	1078.0	1320.5	1588.0	1780.0
C + N_{125}	310.0	624.0	802.5	946.0	1101.5	1330.0	1600.5	1795.0
C + FYM_5 + N_{125}	320.5	626.0	810.0	953.0	1098.5	1338.5	1622.5	1814.5
C + N_{20+105}	311.0	625.5	815.5	968.0	1080.0	1348.5	1588.5	1802.5
C + N_{30+95}	310.5	624.5	814.0	973.5	1084.5	1341.0	1612.0	1794.0
C + N_{20+130}	321.0	636.5	851.5	1011.5	1156.0	1397.5	1644.0	1824.5
C + N_{30+120}	322.0	632.0	847.5	1005.0	1148.0	1381.0	1656.5	1836.5
C + FYM_5 + N_{20+105}	310.5	622.5	814.0	983.5	1107.0	1345.5	1643.5	1802.5
C + FYM_5 + N_{30+95}	315.5	628.0	814.5	994.0	1094.0	1341.0	1640.0	1805.5
C + FYM_5 + N_{20+130}	321.5	634.5	853.0	1022.0	1156.5	1396.0	1674.0	1849.5
C + FYM_5 + N_{30+120}	322.5	637.0	857.5	1028.0	1170.5	1416.5	1690.0	1850.2
CD (p=0.05)	17.6	22.5	32.3	38.5	35.2	41.8	39.6	44.3

Table 6. Helio thermal units of happy seeder sown wheat as affected by different residue and nitrogen management practices (Data pooled over two years, 2016-17 and 2017-18)

Treatments	Helio thermal units (°C day hour)							
	CRI	Maximum tillering	50 per cent booting	50 per cent heading	Anthesis	Milking	Dough	Maturity
NC + N_{1c25}	1787.0	3280.5	4242.0	5184.0	6319.0	8324.0	10916.5	12433.0
C + N_{125}	1786.5	3309.0	4258.5	5233.5	6474.5	8430.5	11025.5	12474.5
C + FYM_5 + N_{125}	1856.0	3327.0	4306.5	5293.0	6476.0	8499.5	11259.5	12705.5
C + N_{20+105}	1787.0	3298.5	4349.0	5388.5	6320.5	8596.5	10916.5	12586.5
C + N_{30+95}	1787.0	3310.0	4304.5	5426.0	6390.0	8529.5	11157.0	12474.0
C + N_{20+130}	1856.0	3412.0	4517.0	5703.5	6981.5	9077.5	11509.5	12825.5
C + N_{30+120}	1856.0	3378.5	4471.0	5651.0	6944.0	8901.5	11635.5	12932.5
C + FYM_5 + N_{20+105}	1787.0	3310.0	4348.5	5480.5	6543.0	8598.5	11471.0	12587.0
C + FYM_5 + N_{30+95}	1811.0	3357.5	4305.0	5569.5	6432.5	8530.5	11509.5	12592.5
C + FYM_5 + N_{20+130}	1856.0	3399.0	4512.0	5820.5	6981.5	9077.5	11845.5	13004.5
C + FYM_5 + N_{30+120}	1856.5	3412.5	4556.5	5878.5	7105.5	9252.5	11892.0	13062.5
CD (p=0.05)	119.5	232.5	289.3	311.2	302.5	345.6	366.8	378.5

Heliothermal units (HTU)

Wheat crop grown with more N consumed more heliothermal units (Table 6) to attain different phenophases. It inferred that nitrogen levels strongly influenced HTU requirement for a particular developmental stage. The crop in treatment C + FYM_5 + N_{30+120} took 13062.0°C day hours to attain physiological maturity, while crop in treatment NC + N_{125} took 12433.0°C day hours for the same. Crop with chopped paddy straw as mulch also recorded higher heliothermal units as compared to unchopped straw treatments.

Photothermal units (PTU)

Different residue and nitrogen management practices strongly influenced PTU requirement for attaining various developmental stages of wheat (Table 7). Treatments receiving higher dose of N fertilizer accumulated more PTU. The cumulative PTU for attaining any phenological stage was

Table 7. Photo thermal units of happy seeder sown wheat as affected by different residue and nitrogen management practices (Data pooled over two years, 2016-17 and 2017-18)

Treatments	Photo thermal units (°C day hour)							
	CRI	Maximum tillering	50 per cent booting	50 per cent heading	Anthesis	Milking	Dough	Maturity
NC + N_{125}	3231.5	6375.0	8217.5	9709.5	11354.0	14164.0	17445.0	19863.5
C + N_{125}	3231.5	6411.5	8267.0	9848.5	11595.5	14278.5	17569.5	20007.5
C + FYM_5 + N_{125}	3345.0	6434.0	8364.5	9926.5	11595.0	14368.5	17840.5	20267.0
C + N_{20+105}	3231.5	6395.0	8417.0	10114.0	11355.0	14487.0	17445.5	20119.5
C + N_{30+95}	3231.0	6411.5	8424.0	10170.5	11425.0	14399.5	17717.0	20007.5
C + N_{20+130}	3345.5	6514.0	8832.5	10572.0	12232.5	15084.0	18111.5	20399.5
C + N_{30+120}	3345.0	6498.5	8782.0	10504.5	12141.5	14878.5	18264.5	20550.0
C + FYM_5 + N_{20+105}	3231.0	6458.5	8418.0	10262.0	11670.0	14487.0	18095.0	20121.0
C + FYM_5 + N_{30+95}	3291.5	6432.0	8423.5	10388.5	11516.5	14398.5	18111.5	20154.5
C + FYM_5 + N_{20+130}	3345.0	6484.5	8829.0	10699.5	12232.5	15084.0	18526.5	20702.5
C + FYM_5 + N_{30+120}	3345.0	6539.5	8879.0	10765.0	12385.0	15296.5	18678.5	20694.0
CD (p=0.05)	184.3	251.6	315.4	421.7	445.0	471.5	508.6	584.5

Table 8. HUE, HTUE and PTUE of happy seeder sown wheat as affected by different residue and nitrogen management practices (Data pooled over two years, 2016-17 and 2017-18)

Treatments	Grain yield (kg/ha)	HUE (kg/°Cday)	HTUE (kg/°Cday hour)	PTUE (kg/°C day hour)
NC + N_{125}	4520	2.54	0.36	0.23
C + N_{125}	4710	2.62	0.38	0.24
C + FYM_5 + N_{125}	4760	2.62	0.37	0.23
C + N_{20+105}	4900	2.72	0.39	0.24
C + N_{30+95}	4970	2.77	0.40	0.25
C + N_{20+130}	5190	2.84	0.40	0.25
C + N_{30+120}	5220	2.84	0.40	0.25
C + FYM_5 + N_{20+105}	5110	2.83	0.41	0.25
C + FYM_5 + N_{30+95}	5190	2.87	0.41	0.26
C + FYM_5 + N_{20+130}	5300	2.87	0.41	0.26
C + FYM_5 + N_{30+120}	5390	2.91	0.41	0.26
CD (p=0.05)	290	0.19	NS	NS

highest in C + FYM_5 + N_{30+120} treatment. To attain physiological maturity, crop under treatment C + FYM_5 + N_{30+120} took maximum (20694.0°C day hours) photothermal units, whereas minimum photothermal units (19863.5°C day hours) to attain maturity were recorded with treatment NC + N_{125}. Higher PTU accumulation under higher N application was due to more number of days taken to reach different phenophases, which might be attributed to extensive vegetative growth due to more N. Presence of straw mulch in chopped straw treatments also resulted in higher cumulative PTU as compared to unchopped treatments.

Heat use efficiency (HUE), helio thermal use efficiency (HTUE) and photo thermal use efficiency (PTUE)

HUE, HTUE and PTUE determine the ability of a plant to convert available heat units, helio thermal and photo thermal units into economic product. Different residue and nitrogen management practices strongly influenced HUE, HTUE and PTUE (Table 8). Wheat crop under treatment C + FYM_5 + N_{30+120} recorded maximum heat use efficiency (2.91 kg/°C days), which was significantly higher than NC + N_{125},C+ N_{125} and C+FYM+ N_{125} treatments, but statistically at par with all other treatments. Heliothermal and photothermal use efficiencies were also higher in treatments receiving more N. Chopped straw treatments had higher values of these efficiencies as compared to unchopped plots. It was observed that better N management in happy seeder sown wheat utilized heat more efficiently.

Conclusion

The study concluded that happy seeder sown wheat with chopped rice straw and better nitrogen management improves microclimate of crop by increasing PAR interception and lowering canopy temperature and increases heat utilization efficiency significantly. Thus, sowing of wheat with happy seeder along with appropriate rise residue and nitrogen management practices can be used quite effectively to manage the menace of rice straw burning and to improve heat utilization efficiency to manage global warming impacts on crop growth and productivity.

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