

Plant Water Relations, Solar Radiation Interception, and Wheat Performance as Influenced by Crop Establishment Methods and Nitrogen Under Extreme Winter Precipitation

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ABSTRACT

Field study was conducted at PDCSR, Modipuram (U.P.) in well drained sandy loam soil (Typic Ustochrept) in pigeon pea based cropping system with wheat (cv. PBW-226) in split-plot design. Treatments consisted of three planting geometry (main-plot) viz., bed planting system (M_1), paired row system of planting (M_2) and conventional planting (M_3) and four levels of nitrogen (sub-plot) viz., 0 (N_0), 60 (N_1), 120 (N_2), and 180 (N_3) kg ha⁻¹ were replicated thrice. Due to exceptionally very high and well distributed precipitation of 168.2 mm between the harvest of preceding short duration pigeon pea and sowing of next wheat, it could be planted very late in the first week of January without pre-sowing irrigation. Crop emergence was delayed considerably and could be initiated on 12th day and completed by 18th day after sowing due to excessive soil moisture. Relatively higher soil moisture content in the profile was found in M_3 compared to M_2 and it was appreciably higher in N_0 compared to N_3 . Higher xylem water potential (XWP) was observed in M_1 compared to M_2 and was maximum in N_0 and the minimum in N_3 . Highest solar radiation interception was found in M_3 and the lowest in M_2 and appreciably higher in N_3 than N_0 . Crop growth was superior in M_3 over M_2 and considerably higher in N_3 compared to N_0 . There was a net saving of 49.1% of water in M_1 compared to M_3 . Substantially higher grain yield (27.9%) was recorded in M_3 compared to M_2 . Almost doubling of yield (97.6%) was found in N_3 over N_0 .

Key words: Xylem water potential, radiation parameters, crop establishment methods, N-nutrition, wheat, excessive winter precipitation.

Introduction

Water and nitrogen are the most limiting factor affecting the plant water relations and the crop performance. Wheat is the staple food of our country, which is grown in diverse situations from rain fed to irrigated conditions. However, more than 85% wheat area is irrigated. Water and nitrogen use efficiency of this crop is low and there is lot of scope for its improvement. Crop establishment methods, nutrient management and type of the preceding crops considerably influence the performance of the succeeding crop in the system. Wheat crop can be planted by several methods viz., conventional, paired rows and bed planting/ridge techniques. There are reports that wheat sowing on

flat beds leads to considerable saving in irrigation water. Recent studies showed that crops like wheat, maize, soybean, cotton and few vegetables could also be grown on beds. This may reduce water and fertilizer inputs as compared with conventional system. Bed-furrow system reduces irrigation requirement as water is applied in furrows only instead of irrigating the entire field. This technology was well adopted by small-scale wheat growers in Yaqui valley of Sonora state of NW Mexico (Agiuno, 1998; Sayre, 1999) and thus has emerged as one of the promising suitable crop management techniques. This technique has the advantage of reducing fuel, water, labour and fertilizer inputs compared to conventional system (Limon *et al.* 2000). Keeping in view the increasing scarcity of

irrigation water, technologies for growing wheat on beds were proposed by (Singh *et al.* 2002). Very little information is available on planting methods and N nutrition of wheat when grown after leguminous crops and the residual effect of preceding crop on wheat is also not characterized. In view of this, an effort was made to characterize the influence of crop establishment methods and nitrogen on plant water relations, solar radiation interception, growth, and irrigation requirement of wheat in legume based cropping system and to find out the suitable planting geometry for improving its performance under excessive winter rains.

Materials and Methods

Field experiment with wheat (cv. PBW 226) in pigeon pea based cropping system was conducted in split-plot design at PDCSR, Modipuram, Meerut in semi-arid tropical climate with an annual average rain fall of 810 mm. The soil was alluvial sandy loam, well drained and with physico-chemical properties of surface layer (0-15 cm): sand 65.3, silt 18.2 and clay 16.5%, pH 7.8, EC 0.179 dS m⁻¹, OC 0.51% and bulk density 1.52 Mg m⁻³. Crop establishment methods [(M₁ : bed planting with 40 cm flat bed and 15 cm ht. and 40 cm furrow, two rows of crop on each bed at 20 cm row spacing, six beds were made manually after field preparation with the removal of soil by spade from furrows and pressed for making it flat, M₂ : conventionally prepared field and planting in paired row system-2 rows at 20 cm and 60 cm open spacing (6 pairs of rows) and M₃ : conventional-20 cm row spacing (26 lines)] in main-plot and four levels of nitrogen in sub-plot viz., 0 (N₀-control), 60 (N₁), 120 (N₂) and 180 (N₃) kg N ha⁻¹ replicated thrice. Crop was sown @ 100 kg seed rate ha⁻¹. Phosphorus and Potassium as P₂O₅ and K₂O @ 60 and 40 kg ha⁻¹, respectively were applied as basal before sowing. Nitrogen was applied in three equal splits at sowing, late jointing and flowering. During *rabi* season, where normal rain fall vary between 60-110 mm, a total of exceptionally very high rain fall (305.2 mm) was received. Out of this 168.2 mm (meteorological weeks: 43rd-66.0, 47th-12.0, 49th-84.2 and 52nd-6.0 mm,) was received before planting of wheat and the pre-sowing irrigation was skipped. But due to this excessive rains, the field could not be prepared in time and it could be sown

exceptionally late on Jan.3,1998. During the crop growing season also, a total of 137.0 mm of precipitation was received which was well distributed (meteorological weeks: 5th-19.0, 7th-7.0, 8th-41.0, 9th-2.0, 10th-41.0 and 11th-27.0 mm) almost raining in every week. This resulted in saving of two irrigations during crop growing season. Due to fairly well distributed rain fall during the crop growing season, only three irrigation on 24 DAS (CRI), 73 DAS (late jointing) and 90 DAS (flowering) were applied and three irrigations equivalent to 180.0 mm (pre-sowing-1 and crop growing season-2) were saved. Solar radiation parameters (radiant energy and light intensity) were recorded at the most active (flowering) stage between 11.30 AM to 12.30 PM on sunny day using portable radiometer (Starlogger-7241) by holding the sensors above at 30 cm and below the crop canopies near soil surface for 10 minutes. Percent interceptions of these parameters were computed. Pre-dawn (between 6.30-7.30 AM at different growth stages) xylem water potentials (XWP) were recorded using portable pressure chamber (PMS-610) apparatus (Scholander *et al.* 1965) on 75, 79, 87 and 94 DAS. Soil moisture at sowing and before first irrigation from different soil layers was estimated thermo-gravimetrically. Data on growth parameters viz., plant height, number of tillers in one meter running row length, ear length and grain yield were recorded at or after harvest.

Results and Discussion

Crop emergence was delayed and was first observed on 12th day after sowing and completed on 18th day, mainly due to excessive soil moisture. In general, crop growth was poor due to very late sowing on account of excessive winter precipitation before planting as well as during the crop growing season. Appearance of nitrogen deficiency symptoms in bed planting system was delayed considerably by 12-15 days compared to conventional method in N₀. It might be because of double layered surface soil system in beds.

Moisture content

In M₁, at sowing, lower soil moisture content (0-10 cm-9.9% and 10-20 cm-16.6%) was found compared to M₃ where it was 18.2 and 22.8% in 0-10 and 10-20 cm soil depths, respectively. But at

20-30 cm depth, considerably higher moisture content was found in M_1 (20.2%) compared to M_3 (17.7%). On 47 DAS, in 0-90 cm soil profile, relatively higher moisture content was found in M_3 followed by M_1 and least in M_2 . This might be because of more evaporation losses of water from more open space between paired rows of the crop. Levels of N has also considerably influenced it. Highest moisture content was found in N_0 followed by N_1 , N_2 and least in N_3 , which might be due to more extraction of water by plants on account of development of better root system and enhanced physiological activities. It was lowest in 0-15 cm, which increased slightly in 15-30 cm, but decreased in 30-60 cm depth and again increased slightly in 60-90 cm depth.

Water requirement

In M_1 , the amount of irrigation water was increased by 32.4 and 36.5% in second and third irrigations, respectively compared to the first irrigation, where 6.0 cm of water was applied, which was mainly due to settling of soils of the beds, which resulted in the increased area of plot for applying irrigation. On the other hand, the amount of water decreased by 30.4 and 27.5% in M_2 and 26.0 and 22.8% in M_3 during the second and third irrigations, respectively compared to first irrigation. This decrease in amount of irrigation water was mainly due to settling of loose soil. The major differences were observed between first and second irrigation while the differences were only minor between second and third irrigation. Overall in M_1 , about 49.1 and 53.6% of irrigation water was saved compared to M_3 and M_2 , respectively. In M_1 , during the first irrigation, the saving was to the tune of 65.6 and 69.5% compared to M_3 and M_2 , respectively. However, during the second irrigation, the saving reduced to 26.0 and 30.4% in M_3 and M_2 , respectively. During the third irrigation, the saving was reduced further to 22.8 and 27.5% in M_3 and M_2 , respectively. Aggarwal and Goswami (2003) also found that as compared to flood irrigation in conventional flat planting, amount of irrigation water applied was lesser in bed planting system at the time of first irrigation as water was applied in furrows only. But differences reduced in second and third irrigation, because of flattening of beds and

furrows in due course of time.

Xylem water potential

During the crop-growing season (75 to 94 DAS-near reproductive stage), N fertilization as well as establishment methods has considerably influenced the plant water relations (Table 1). At any crop stage, higher XWP was recorded in M_1 followed by M_3 and the lowest in M_2 which might be mainly due to more bare soil surface in M_2 leading to higher water losses through evaporation from bare soil leading to water stress and consequently decline in XWP. Visually there was more drying of surface soil in paired row planting as compared to bed and conventional. In general, higher XWP was found in N_0 followed by N_1 , N_2 and lowest in N_3 . This might be due to higher transpirational losses due to higher LAI, root activity and extraction of soil water with increasing levels of nitrogen from 60-180 kg ha⁻¹. On 75 DAS, highest XWP was recorded in M_1 (-1.64 MPa) followed by M_3 (-1.74 MPa) and lowest in M_2 (-1.83 MPa) which was 11.6% lower than M_1 . Highest XWP was observed in N_0 (-1.32 MPa) followed by N_1 (-1.53 MPa), N_2 (-1.87 MPa) and lowest in N_3 (-2.22 MPa) which was 15.9, 41.7 and 68.2% lower in N_1 , N_2 and N_3 , respectively compared to control. It indicates that crop was more stressed at this stage. On 79 DAS, a recovery in XWP was observed which might be due to irrigation/rains. Relatively, higher XWP was found in M_1 (-1.46 MPa) followed by M_3 (-1.52 MPa) and lowest in M_2 (-1.60 MPa) which was 9.8% lower than M_1 indicating the reducing i.e., more narrowing down of the differences. Similarly, considerably higher XWP was observed in N_0 (-1.19 MPa) followed by N_1 (-1.38 MPa), N_2 (-1.61 MPa) and lowest in N_3 (-1.91 MPa), which was 16.0, 35.3 and 60.5% lower in N_1 , N_2 and N_3 , respectively than N_0 . Almost, a similar trend but with lower magnitude was observed on 87 DAS. But, on 94 DAS, the differences between the values of XWP were much larger in different establishment methods as well as levels of N. The higher XWP in control and lower levels of N might be due to reduced water extraction and up take by roots due to their poor growth.

Solar Radiation parameters

Radiant energy and light intensity were considerably influenced by crop establishment methods as well as N fertilization (Table 2). But these were more influenced by N fertilization compared to establishment methods. At all the levels of N, higher interception of radiant energy was recorded in M_3 followed by M_1 and lowest in M_2 which increased from 39.6 in N_0 to 82.5% in N_3 under M_2 , 44.9 to 83.4% under M_1 and 46.8 to 87.3 under M_3 . In M_2 , it was 39.6, 59.2, 73.0 and 82.5% in N_0 , N_1 , N_2 and N_3 , respectively. While in M_1 , it was 44.3, 62.4, 74.8 and 83.4% in N_0 , N_1 , N_2 and N_3 , respectively. In M_3 , it was 46.8, 65.7, 83.4 and 87.3% in N_0 , N_1 , N_2 and N_3 , respectively. Highest light intensity interception was observed in M_3 followed by M_1 and lowest in M_2 (Table 2). The lowest interception was observed in N_0 and the highest in N_3 . In M_2 , it was 40.3, 81.9, 91.8 and 93.5% in N_0 , N_1 , N_2 and N_3 , respectively. While in M_1 , it was 44.4, 84.1, 95.7 and 96.1% in N_0 , N_1 , N_2 and N_3 , respectively. In M_3 , it was 55.7, 92.7, 97.0 and 97.6% in N_0 , N_1 , N_2 and N_3 , respectively. The higher radiation interception in conventional method of planting and with 180 kg N ha⁻¹ might be due to better canopy development and higher LAI, where crop canopies absorb most of the radiation and least is allowed to pass through it.

Crop growth

Growth parameters viz., plant height, number of tillers and ear length were highly influenced by N nutrition but not much affected by establishment methods (Table 3). Maximum influence of N fertilization was observed on ear length, followed by number of tillers and least on plant height. Tallest plants were found in M_3 (88.2 cm) and the shortest in M_2 (83.3 cm), which was 5.9% higher, compared to M_2 . Similarly, tallest plant was observed in N_3 (93.6 cm) followed by N_2 (88.3 cm), N_1 (84.3 cm) and shortest in N_0 (77.7 cm) which was 20.5, 13.3 and 8.5% higher in N_3 , N_2 and N_1 , respectively compared to N_0 . Relatively, more tillers were found in M_3 (82.8), which were 5.1% higher than M_2 (78.8). Highest number of tillers were recorded in N_3 (90.0) followed by N_2 (84.3), N_1 (79.7) and

lowest in N_0 (70) which were 13.9, 20.4 and 28.6% higher in N_1 , N_2 and N_3 , respectively compared with N_0 . Highest ear length was found in M_3 (8.8 cm) and the lowest in M_2 (8.3 cm), which was 6.0% higher than M_2 . Appreciably higher ear length was found in N_3 (10.0 cm) followed by N_2 (9.2 cm), N_1 (8.4 cm) and the lowest in N_0 (6.5 cm), which was 25.2, 41.5, and 53.8% higher in N_1 , N_2 and N_3 , respectively compared to N_0 .

Productivity

Crop establishment methods as well as N fertilization has considerably influenced the grain yield of wheat. However, the influence of N fertilization was more compared to establishment methods. In general, the grain yield was extremely low because of very late planting of the crop and unfavourable weather conditions. Highest grain yield was recorded in M_3 (13.5 q ha⁻¹) followed by M_1 (12.3 q ha⁻¹) and the lowest in M_2 (10.4 q ha⁻¹), which was 18.3 and 27.9% higher in M_1 , and M_3 , respectively compared with M_2 . Maximum grain yield was found in N_3 (16.4 q ha⁻¹) followed by N_2 (12.9 q ha⁻¹), N_1 (10.5 q ha⁻¹) and the minimum in N_0 (8.3 q ha⁻¹), which was 26.5, 55.4 and 97.6% higher in N_1 , N_2 , and N_3 , respectively compared to N_0 . Even an increase of 27.1% was recorded in N_3 compared to N_2 indicating that the crop responded up to 180 kg N ha⁻¹ and the recommended dose of 120 kg N ha⁻¹ for such soils have become sub-optimal and needs revision.

Conclusions

It can be concluded that about 49.1% of irrigation water could be saved with bed planting compared to conventional planting but the over all performance of wheat was superior with conventional method due to maintenance of favourable plant water status, higher solar radiation interception, superior crop growth and yield contributing parameter. For getting the highest productivity of wheat, it should be planted with conventional method at 20 cm row spacing and 180 kg N ha⁻¹ applied in three equal splits at CRI, jointing and flowering as 120 kg N ha⁻¹ have become sub-optimal in sandy loam soil.

Table 2. Influence of crop establishment methods and nitrogen on solar radiation parameters of wheat in pigeon pea based cropping system

Treatments	N ₀			N ₁			N ₂			N ₃		
	Above canopy	Below canopy	Intercep- tion (%)	Above canopy	Below canopy	Intercep- tion (%)	Above canopy	Below canopy	Intercep- tion (%)	Above canopy	Below canopy	Intercep- tion (%)
	Radiant energy (W m ⁻²)											
M ₁	841.4	463.3	44.9	851.5	320.3	62.4	866.8	218.3	74.8	892.4	147.7	83.4
M ₂	838.0	506.2	39.6	848.1	346.0	59.3	858.3	232.0	73.0	883.9	155.0	82.5
M ₃	838.6	392.5	46.8	854.9	293.2	65.7	865.3	144.0	83.3	901.0	114.0	87.3
	Light intensity (K. Lux)											
M ₁	97.6	54.3	44.4	99.4	15.8	84.1	101.1	4.3	95.7	102.8	4.0	96.1
M ₂	98.8	59.0	40.3	100.6	18.2	81.9	102.1	8.4	92.3	100.3	6.5	93.5
M ₃	98.2	43.5	55.7	100.0	7.3	92.7	100.3	3.0	97.0	102.6	2.5	97.6

Table 3. Influence of crop establishment methods and nitrogen on wheat growth in pigeon pea based cropping system

Treatments	Plant height (cm)						Number of tillers, 1 m row						Ear length (cm)		
	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean	N ₀	N ₁	N ₂	N ₃	Mean
M ₁	80.1	83.7	88.1	94.0	86.5	70	81	84	90	81.3	64	8.5	9.2	10.0	8.5
M ₂	72.3	83.1	87.7	90.0	83.3	67	76	83	89	78.8	63	8.0	8.7	9.9	8.3
M ₃	80.6	86.1	89.2	96.9	88.2	73	82	86	91	82.8	69	8.6	9.7	10.1	8.8
Mean	77.7	84.3	88.3	93.6	86.5	70	79.7	84.3	90	81.3	65	8.4	9.2	10.0	8.5

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