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Effect of tillage and irrigation on solar radiation interception, leaf water potential and productivity of wheat in rice based cropping system

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ABSTRACT

Field experiments were conducted in sandy loam well drained alluvial *Typic Ustochrept* soils at Modipuram, Meerut (UP) to study the influence of levels of tillage and irrigation schedules on interception of solar radiation components, leaf water potential (LWP) and productivity of wheat in rice-based cropping system during (1997-98). The field was continuously under rice-wheat rotation during 1994-95 to 1997-98. Substantially higher radiation was intercepted under direct seeded as compared to puddled condition. Lower LWPs (pre-dawn and mid-day) were found under direct seeded as compared to puddled conditions. Levels of tillage as well as irrigation schedules have significantly influenced the grain yield and total harvestable biomass. The results indicate the adverse effect of puddling practices adopted in preceding rice crop on the succeeding crop of wheat in the system.

Key Words : PAR, radiant energy, light intensity, leaf water potential, tillage, rice-wheat system

Out of the total solar radiation, only photo synthetically active radiation (PAR) is utilized for photosynthesis and its rate depends upon the amount of PAR intercepted by the canopy. The visible part of solar radiation governs yield and total weight of plant structure, the size of leaves and root development. Tillage practices adopted over a longer period of time in one crop ably size influence the establishment and performance of succeeding crop in the system.

Boyer (1996) observed the need to improve use efficiency of water by achieving more photosynthate per unit of water transpired by the plant thus economizing the water requirement. Water stress in the plant is known to directly reduce photosynthesis and in general, it declines after a reduction of 30% of moisture from the leaves. Turner (1997) reported that the rapid rate of development of water deficits results in reduced grain yield, small grain size, grain growth, photosynthesis and water use efficiency. In view of the above, an attempt was made to study the influence of tillage practices and irrigation schedules on solar radiation interception, leaf water potential and productivity of wheat in rice based cropping system.

MATERIALS AND METHODS

Field experiments were conducted at Research Farm of Project Directorate for Cropping Systems Research, Modipuram, Meerut, Uttar Pradesh (29° 4' N Lat., 77° 46' E Long. and 237 m amsl) in semi-arid sub-tropical climate with an average rainfall of 810 mm. The soil of the study area was *Typic Ustochrept*, alluvial sandy loam well drained, and with physico-chemical properties of surface layer (0-15cm): sand 65.3%, silt 18.2%, clay 15.5%, pH 7.8, electrical conductivity 0.179 dS m^{-1}, organic carbon 0.51% and bulk density 1.52 Mg m^{-3}. Experiments were conducted in rice-wheat crop sequence during four crop cycles (1994-95 to 1997-98) with rice (Saket- 4) and wheat (HD-2285) as test crops in split plot design replicated four

Table 1: Treatments details of the experiment in rice-wheat cropping system

Rice	Wheat
Levels of tillage (main-plot)	
Transplanted	
T_1-Conventional puddling (4 passes of puddler)	Conventional tillage (2 harrow + 2 cultivator)
T_2-Conventional puddling (4 passes of puddler)	Reduced tillage (1 harrow + 1 cultivator)
T_3- Reduced puddling (2 passes of puddler)	Conventional tillage (2 harrow + 2 cultivator)
T_4- Reduced puddling (2 passes of puddler)	Reduced tillage (1 harrow + 1 cultivator)
Direct seeded	
T_5-Conventional tillage (2 harrow + 2 cultivator)	Conventional tillage (2 harrow + 2 cultivator)
T_6-Conventional tillage (2 harrow + 2 cultivator)	Reduced tillage (1 harrow + 1 cultivator)
T_7-Reduced tillage (1 harrow + 1 cultivator)	Conventional tillage (2 harrow + 2 cultivator)
T_8-Reduced tillage (1 harrow + 1 cultivator)	Reduced tillage (1 harrow + 1 cultivator)
Irrigation schedules (sub-plot)	
Well watered	
I_1-Saturation to submergence (5 ± 2.5 cm)	Recommended irrigations (five) at all physiological growth stages
Limited water	
I_2-Irriagation at initiation of soil cracking	Three irrigations at crown root initiation (CRI), late jointing and milk stages

times in 10.0 m x 7.2 m plot. Treatments (Table 1) comprised of eight tillage combinations (main-plot) and two irrigation schedules (sub-plot).

Data on various parameters viz. solar radiation, leaf water potential (LWP), plant height, yield and yield attributes were recorded during wheat crop of 1997-98. During the growing season of the crop, a total rainfall of 239.4 mm was received (Fig.1). Maximum and minimum temperatures ranged between 14.0-39.8 °C and 6.6-28.2 °C respectively. Bright sunshine hours ranged between 0.9 to 9.4 hours. Wheat crop was sown on November 12, 1997 and harvested on April 25, 1998. Solar radiation parameters (PAR, incident solar radiation and light intensity) were recorded on 84 (flowering) and 117 (milk) days after sowing (DAS) in selected treatment combinations T_1I_1 (puddled well watered), T_1I_2 (puddled limited water), T_5I_1 (direct seeded well watered) and T_5I_2 (direct seeded limited water). These parameters were recorded between 11.30 AM to 12.30 PM on bright sun shine day using portable Radiometer (Starlogger – 7241, Australia) 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 and mid-day leaf water potentials were recorded using portable pressure chamber (Model PMS-610) apparatus (Scholander *et al* 1965). For this, a well-developed fully expanded leaf was randomly selected (second from the top till heading stage and flag leaf thereafter) in the plant and cut at the ligule. Observations were recorded from three plants in each plot and the mean values are reported. Pre-dawn LWPs were measured on 111 (milk), 119 (milk) and 125 DAS (dough) and mid-day LWPs were measured on 82 (flowering) and 110 DAS (milk). The rates of fall and recovery of pre-dawn LWPs were computed on 119 (milk) and 125 DAS (dough) stages after the application of 3rd irrigation on 118 DAS.

Plant height was measured at crop harvest. Total harvestable biomass and grain yield and yield attributes (ear length and no. of ears m^{-2}) were also recorded. Due to fairly well distributed rainfall (239.4 mm) during the crop-growing season, only three irrigations on 53 (maximum tillering), 86 (flowering) and 118 (milk) DAS were applied in well-watered treatment, while in limited water treatments, only two irrigations on 53 (maximum tillering) and 118 DAS (milk) were applied. Crop was sown without pre- sowing irrigation due to receipt of sufficient rains (66 mm) prior to field preparation. Studies were conducted in the same field without disturbing the layout consequently for four crop cycles.

RESULTS AND DISCUSSION

Influence on solar radiation parameters

Higher solar radiation (PAR, radiant energy and light intensity) were intercepted under well watered as compared to limited water conditions, under direct seeded condition as compared to puddled and on 117 DAS (milk) as compared to 84 DAS (flowering) (Table 2). Differences between various treatments narrowed down considerably at advanced stages of crop growth as compared to initial stage.

Interception of radiation components

At flowering stage (84 DAS), under direct seeded as well as puddled condition, the differences in PAR interception between

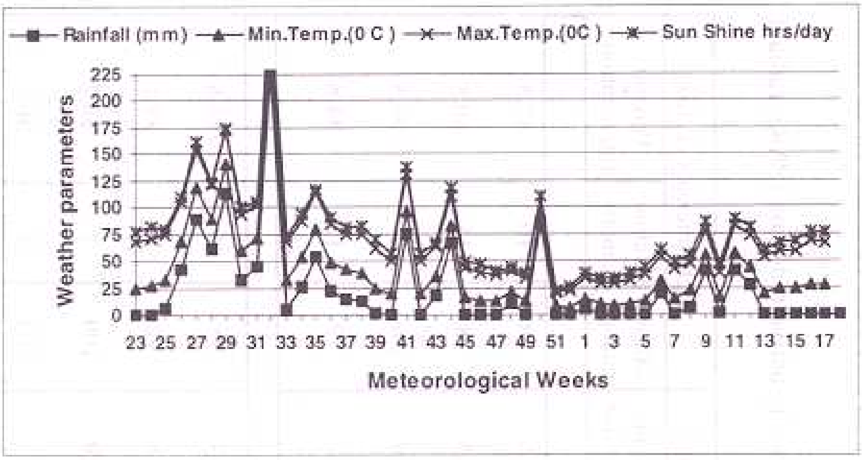

Fig.1: Weekly averages weather parameters during rice-wheat crop cycle (1997-98)

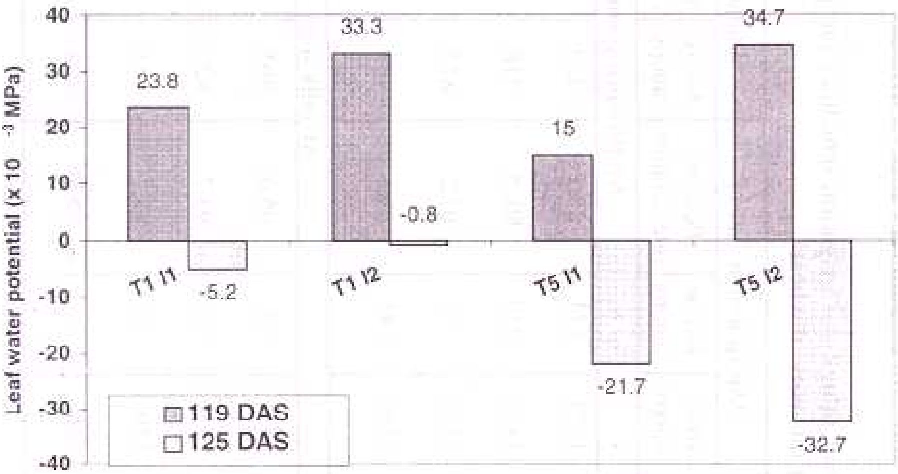

Fig.2 : Effect of tillage and irrigation schedules on rate of change of pre dawn leaf water potential of wheat

limited water and well-watered condition were appreciably higher (Table 2). It was appreciably higher under direct seeded compared with puddled condition.. This might be due to canopy development differences in direct seeded as compared to puddled condition. Under both limited and well watered conditions, on 84 and 117

Table 2: Effect of levels of tillage and irrigation schedules on photo synthetically active radiation (PAR), radiant energy and light intensity in wheat

Treatment	PAR (μ mol m^{-2} sec^{-1})			Radiant energy (Wm^{-2})			Light intensity (k. lux)		
	Above canopy	Below canopy	Percent interception	Above canopy	Below canopy	Percent interception	Above canopy	Below canopy	Percent interception
	At flowering stage								
Puddled-well watered (T_1I_1)	1259	174	86.2	720	147	79.6	80	10	87.5
Puddled- limited water (T_1I_2)	1174	229	80. 5	718	169	76.5	78	15	80.8
Direct seeded- well watered (T_5I_1)	1383	39	97.2	815	108	86.7	86	3	96.5
Direct seeded - limited water (T_5I_2)	1358	141	89.6	781	135	82.7	79	12	84.8
At milk stage									
Puddled-well watered (T_1I_1)	1621	71	95.6	865	132	84.7	98	6	93.8
Puddled -limited water (T_1I_2)	1535	97	93.7	826	150	81.8	92	10	89.1
Direct seeded - well watered (T_5I_1)	1791	32	98.2	943	67	92.9	109	2	98.2
Direct seeded1 limited water (T_5I_2)	706	72	95.8	904	84	90.7	103	4	96.1

DAS, the amount of intercepted PAR was higher in direct seeded compared to puddled condition. The higher interception of PAR under well-watered condition was attributable to higher biomass production and better canopy development. Thomson and Siddique (1997) found that the grain legume species, which produced larger biomass, intercepted greater amount of photosynthetically active radiation (PAR). Calderini *et al.* (1997) also observed that the change in the architecture of the canopies in wheat crop influences the radiation interception, radiation use efficiency and crop growth rates.

Radiant energy and light intensity

In these cases also, relatively higher interception percentage was noticed (Table 2) in the direct seeded well-watered treatment. Both at flowering and milk stages, PAR and light intensity have same level of interception in the respective treatments with relatively higher interception under direct seeded and well-watered treatment. Radiant energy interception was slightly lower. Compared with milk stage, interception in radiation components was around 5 percent lower at flowering stage. Below canopy transmission was lower in direct seeded treatments at both growth stages suggesting better canopy growth and consequent better absorption in these treatments.

Pre-dawn LWP

Under well-watered condition, on 111 DAS, higher LWP was recorded under puddled as compared to direct seeded condition (Table 3) but after 3rd irrigation on 118 DAS, it increased to – 0.09 MPa both under puddled as well as direct seeded conditions. On the other hand, under limited water condition, on 111DAS, relatively lower LWP of – 0.21 and – 0.23 MPa was recorded under puddled and direct seeded condition, respectively. At all the stages, relatively higher LWP was recorded under puddled compared with direct seeded condition. It was minimum on 119 DAS ranging from –0.09 to –0.12 MPa. Higher LWP was recorded in treatments (T_5I_1) viz. –0.23 MPa at 111 DAS and –0.30 MPa at 125 DAS corresponding to milk and dough stages respectively.

Under limited water conditions, at 119 DAS, higher rate of recovery of LWP was recorded under direct seeded (34.7×10^{-3} MPa d^{-1}) as compared to puddled (33.3×10^{-3} MPa d^{-1}) condition. On the other hand, under well watered condition, higher rate of recovery of LWP was recorded under puddled (23.8×10^{-3} MPa d^{-1}) as compared to direct seeded condition (15.0×10^{-3} MPa d^{-1}) (Fig. 2). On 125 DAS (dough), under limited water conditions, higher rate of decline of LWP was observed under direct seeded (-32.7×10^{-3} MPa d^{-1}) as compared to puddled (-0.8×10^{-3} MPa d^{-1}) condition. This might be due to higher water losses because of denser canopy development and more transpirational losses.

Mid-day LWP

Under limited water conditions, on 82 DAS, higher LWP was recorded under puddled (-1.45 MPa) as compared to direct seeded condition (-1.53 MPa) (Fig. 3). Almost similar values of LWP were observed on 110 DAS. The lower LWP in direct seeded conditions might be due to higher solar radiation interception that might have lead to higher transpiration losses. Subramaniam and Venktateswarlu

Table 3: Effect of tillage and irrigation schedules on pre-dawn leaf water potential LWP, (MPa) of wheat

Treatments	LWP (MPa)		
	111 DAS (Milk)	119 DAS (Near dough)	125 DAS (Dough)
Puddled - well watered (T_1I_1)	-0.17	-0.09	-0.12
Puddled - limited water (T_1I_2)	-0.21	-0.12	-0.12
Direct seeded - well watered (T_5 I_1)	-0.19	-0.09	-0.22
Direct seeded - limited water (T_5 I_2)	-0.23	-0.10	-0.30

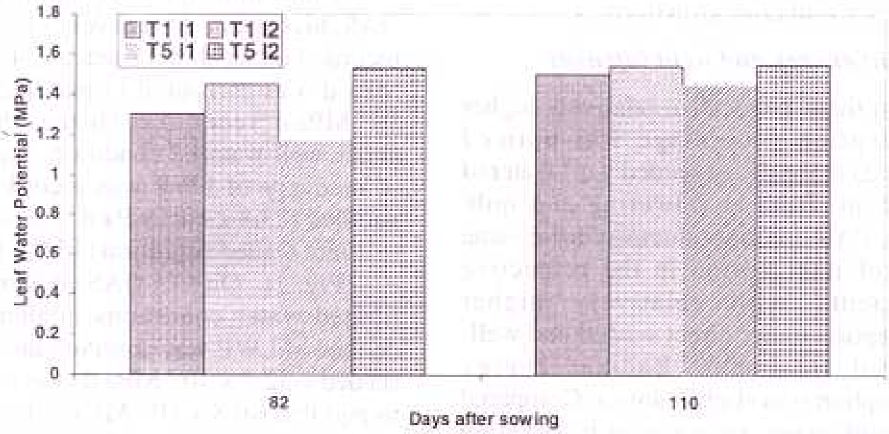

Fig. 3 : Effect of tillage and irrigation schedules on mid-day leaf water potential of wheat

(1995) have also found inverse relationship between PAR and leaf water potential in rainfed castor.

Under well watered conditions, on 82 DAS, higher LWP was recorded under direct seeded (-1.17 MPa) as compared to puddled condition (-1.30 MPa) and almost the same trend was observed on 110 DAS but the differences narrowed down considerably (Fig. 3). This might be due to better root growth under direct seeded conditions because of favorable soil physical environment.

Yield and yield attributes

Plant height and yield attributes (ear length and number of ears m^{-2}) were appreciably influenced by levels of tillage and irrigation schedules (Table 4). Substantially higher plant height, ear length and number of ears m^{-2} were recorded under

Table 4: Effect of levels of tillage and irrigation schedules on plant height, yield and yield attributes of wheat

Treatments	Plant height (cm)	No. of ears (m^{-2})	Ear length (cm)	Grain yield ($t\ ha^{-1}$)	Total harvestable biomass ($t\ ha^{-1}$)
Puddled-well watered (T_1I_1)	81.4	377	9.6	3.89	9.34
Puddled- limited water (T_1I_2)	72.0	368	9.4	3.67	8.60
Direct seeded- well watered (T_sI_1)	87.0	397	10.6	4.05	9.67
Direct seeded -limited water (T_sI_2)	79.7	389	10.2	3.74	9.07
	C.D. (0.05)		Till x Irri.	0.17	0.47

direct seeded as compared to puddled conditions.

Grain yield and total harvestable biomass of wheat was significantly influenced by levels of tillage as well as irrigation schedules (Table 4). Significantly higher grain yield was recorded under direct seeded (3.90 t ha^{-1}) as compared to puddled conditions (3.78 t ha^{-1}) indicating effect of puddling practices adopted in preceding rice crop on succeeding crop of wheat in the system. In direct seeded conditions, maximum grain yield was recorded under well watered (4.05 t ha^{-1}) which was significantly higher than under limited water condition (3.74 t ha^{-1}). Similarly in puddled condition, maximum grain yield was obtained under well-watered treatment.

It can be concluded that the optimum yield of wheat in rice based cropping system could be obtained when it was grown after direct seeded rice under well watered condition on account of better solar radiation interception, leaf water status, plant growth and relatively higher yield contributing parameters. Puddling practices adopted in preceding rice crop affect the yield of succeeding wheat in the system due to its adverse impact on soil physical environment.

REFERENCES

Boyer, J.S. 1996. Advances in drought tolerance in plants. *Advances Agron.*, 56: 187-218.

Calderini, D.F., Dreccer, M.F. and Slafer, G.A. 1997. Consequences of breeding on biomass, radiation interception and radiation use efficiency in wheat. *Field Crops Res.*, 52 (3): 271-281.