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Variation and influence of LAI and PAR on rice yield under different site specific nutrient management practices

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Abstract
A field experiment was carried out to study the influence of leaf area index and PAR interception on yield of rice under different SSNM practices. Leaf area index increased continuously and plateau at flowering stage and similar trend was noticed in PAR interception and it commensurate with LAI. The results indicated a significant increase in leaf area index and PAR interception in SR-2 over Jhelum which consequently led to its higher grain yield. Among the different SSNM practices, significantly higher LAI and PAR interception was recorded for the treatments which received higher application of nutrients particularly nitrogen. Nutrient Expert guided treatment recorded the highest LAI and PAR interception over all other treatments except LCC 5 which was found at par with it. NE^R recorded significantly higher grain yield over recommended practice and LCC 4 and all other treatments studied. The decrease in growth parameters like LAI and PAR was greatest in case of omission plot. The decrease in growth parameters and final yield among other nutrient omissions was greatest due to omission of nitrogen and was followed by P and K omission. The study determined the significance of LAI and PAR interception on the yield of rice. The nutrient expert guided nutrient management practice was found significantly better over other nutrient guided practices in achieving optimum LAI and PAR interception which translated into higher grain yield. The study determined the importance of SSNM practices on leaf area index and PAR interception in rice crop and its consequent effect on final grain yield.

Keywords: SSNM, LAI, PAR interception, Nutrient expert, LCC, Grain yield

Introduction
Rice (*Oryza sativa* L.) is typically a thermophilic tropical crop and its cultivation under temperate conditions like Kashmir requires proper adjustment to synchronise the different critical crop developmental phases with favourable weather conditions. Different management practices and weather conditions play a pivotal role in getting higher dividends from the crop. Balanced fertilization plays dominant role in increasing different growth parameters which ultimately translates into higher yield. Leaf area index is a vital index of crop growth and a major character influencing the assimilating capacity of the crop and ultimate productivity (Watson, 1947) [11]. To achieve high yield, maximization of leaf area is an important factor of the crop (Singh and Agarwal, 2001) [8] as it influences the level of light penetration and interception by the crop and consequently the crop yield. The interception of photosynthetic ally active radiation gives a measure of plants ability to absorb the photosynthetic ally active radiation used for photosynthesis. Quantity and quality of radiation intercepted influences photosynthesis efficiency of higher plants (Ghassemi-Golezani *et al*. 2013) [2]. Intercepted radiation is the difference between light received at the canopy surface and that transmitted through the canopy (Squire, 1990) [9]. PAR interception exhibits positive correlation with the photosynthates production and biomass production (Juan *et al*. 2013) [3]. Significant positive correlation between leaf area index and PAR interception has been found and their influence on final grain yield. Increase in LAI and PAR interception with improvement in nutrient management has been widely acknowledged (Darmadeh, 2011, Tang *et al.* 2017, Mannade, 2017, Police-Patil, 2011) [1, 10, 4, 6]. Therefore, the present study was carried out to find the role of leaf area index and interception of photosynthetic ally active radiation (PAR) on the grain yield of rice.

Materials and methods

The field experiment was conducted at Mountain Research Centre for Field Crops, Khudwani of Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir during *kharif* 2016 and *kharif* 2017, respectively. The experimental site is situated in temperate zone of the state between 34° N latitude and 74° E longitude at an altitude of 1560 metres above mean sea level. Climatically the experimental site was in mid altitude temperate zone characterised by hot summers and very cold winters with an average annual precipitation of 812 mm (average of past 20 years) most of which is received from December to April in the form of snow and rains. The experiment was carried out in factorial randomised complete block design with one factor as varieties (SR-2 and Jehlum) and other as nutrient management practices (Recommended practice $N_{120}P_{60}K_{30}Zn_{15}$, Nutrient expert Recommendation NE^R $N_{141}P_{51}K_{75}Zn_{15}$, NE^R+ N_{110} based on LCC 4 @ 20 kg ha^{-1}, NE^R+ N_{130} based on LCC 5 @ 20 kg ha^{-1}, absolute control $N_0P_0K_0Zn_0$, N-omission plot $N_0P_{51}K_{75}Zn_{15}$, P-omission plot $N_{141}P_0K_{75}Zn_{15}$, K-omission plot $N_{141}P_{51}K_0Zn_{15}$, Zn-omission plot $N_{141}P_{51}K_{75}Zn_0$) replicated thrice. Periodic LAI and PAR interception was recorded at important crop growth stages viz. 30, 60 and 90 days after transplanting (DAT) and pooled over the period of two years. LAI was measured using the manual method. PAR interception was measured by PAR intercept-meter (AccuPAR LP-80, Decagon Devices, USA). Yield from each plot was recorded separately as kg $plot^{-1}$ and then converted into t ha^{-1}. Data was analysed by using OP-STAT software (Sheoran *et al.* 1998) [7].

Results and discussion

Leaf area index (LAI)

Significant difference was recorded between the two varieties owing to different nutrient management practices (Table 1). LAI was found significantly higher at important critical crop growth stages viz. 60 and 90 DAT coinciding with panicle initiation and flowering stages of rice crop, however, the two varieties were at par with each other at 30 DAT which may be due to the fact that in SR-2 initial growth is low and increases substantially at later period of crop growth. The interception of photosynthetic ally active radiation by the two varieties was found to increase in similar fashion and was higher in SR-2 over Jhelum due to the higher LAI in SR-2. This might be due to the genetic makeup of the two varieties. The increase in LAI and PAR interception in SR-2 over Jhelum translated in higher grain yield. The variety SR-2 recorded taller plants which lead to increase in leaf number and also the leaves of SR-2 were found broader and thicker in size which eventually has lead to higher LAI in SR-2 than Jehlum. Moreover, the longer growth duration of SR-2 might have enabled accumulation of more photosynthetic assimilates. The results were in conformity with the findings of Police-Patil (2011) [6] who also reported differences in the growth parameters like LAI due to different genetic makeup of varieties. Similar results were also reported by Zhao *et al.* (2015). Among the different nutrient management approaches significant differences were found in LAI (Table 1). The treatments NE^R, LCC 5, LCC 4 and recommended practice were found at par with each other up to 30 DAT however, from 45 DAT NE^R recorded significantly higher LAI but was at par with LCC 5 and Zn omission plot. The similar LAI between recommended practice and other SSNM plots initially might be due to higher basal application (50%) in the recommended plots which have supported initial higher growth, however with the advancement in the growing season the blanket application was not able to synchronise with the crop demand while in case of other SSNM plots like NE and LCC 5 the nutrient application was more balanced and there was greater congruence between nutrient supply and crop demand. Moreover, the higher application of N in NE led to increase in plant height and tiller number which subsequently increased the LAI. Also, the increasing trend of LAI in NE and LCC 5 at higher nitrogen levels can be attributed to the positive effect of nitrogen on both leaf development and leaf area duration (Fageria, 2007). Significantly lower LAI was recorded for the absolute control followed by N-omission plot which might be due to less availability of nutrients particularly of nitrogen. Other omission plots like P and K also recorded lower LAI than NE^R but were significantly higher than N-omission plot which indicated importance of N in better growth of rice. Higher LAI with SSNM practice using balanced dose of major nutrients like NPK and decrease in growth parameters with omission of one or two nutrients were also reported by Nath *et al*. (2013) [5] and Manade (2017), Police-Patil (2011) [6] and Xu *et al*. (2016) [12].

Photosynthetic ally active radiation (PAR)

Significant difference was observed in PAR interception between the two varieties from 45 DAT onwards with SR-2 accumulating more PAR than Jehlum (Table 1). This might be due to greater LAI in SR-2 which have enabled in more interception of PAR. Greater PAR interception due to higher LAI was also reported by Patidar *et al*. (2018). Significant difference in PAR interception was also recorded among the various nutrient management practices (Table 1). Both NE^R and LCC 5 recorded higher PAR interception than recommended practice and LCC 4 which might be due to higher and timely nutrient application in these treatments which lead to increased LAI and subsequently more PAR interception. Lowest PAR interception was recorded in absolute control followed by N, P and K omission plots. Higher PAR interception with increased N fertilization levels were also reported by Patidar *et al*. (2018). Similar results were also reported by Darmadeh (2011) [1] and Tang *et al.* (2017) [10].

Grain yield

The increase in LAI and PAR interception was found to commensurate directly with the grain yield. Grain yield was affected significantly due to different SSNM practices and was higher in NE^R and LCC 5 guided management practice (Table 1). The higher leaf area index and PAR interception in Nutrient Expert Recommended fertilizer dose lead to higher accumulation of photosynthates which translated into higher grain yield. Significant positive effect of LAI and PAR interception was found on the final economical yield of rice (Darmadeh, 2011, Juan *et al.*, 2013, Tang *et al.*, 2017, Mannade, 2017) [1, 3, 10, 4].

Table 1: Effect of SSNM practices on LAI, PAR and grain yield in rice pooled over 2016 and 2017

Treatments	LAI			PAR interception			Grain Yield (t ha^{-1})
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	
Varieties							
SR-2	0.82	3.39	5.13	29.47	82.39	89.89	7.28
Jehlum	0.84	3.16	3.83	31.68	78.99	76.78	6.43
S.Em ±	0.01	0.03	0.04	0.73	1.06	1.01	0.09
CD (p≤ 0.05)	NS	0.09	0.11	NS	3.06	2.89	0.25
Nutrient Management Practices							
Recommended Practice	0.82	3.36	4.74	32.07	79.59	81.93	6.98
Nutrient Expert Recommendation (NE^R)	0.92	3.65	5.20	33.47	92.25	93.09	8.77
LCC≤ 4 @ 20 kg ha^{-1}	0.79	3.47	4.83	29.72	83.92	86.55	7.48
LCC≤ 5 @ 20 kg ha^{-1}	0.87	3.60	5.20	31.20	90.00	91.47	8.29
Absolute control ($N_0P_0K_0ZN_0$)	0.75	2.52	3.18	25.70	63.36	66.61	3.60
Nitrogen omission plot (–N)	0.77	2.75	3.54	28.06	70.29	73.32	4.60
Phosphorous omission plot (–P)	0.83	3.27	4.13	30.51	76.79	81.57	6.46
Potassium omission plot (–K)	0.85	3.34	4.39	31.62	80.30	84.71	6.94
Zinc omission plot (–Zn)	0.89	3.55	5.12	32.83	89.71	90.78	8.60
S.Em ±	0.03	0.06	0.08	1.55	2.25	2.13	0.18
CD (p≤ 0.05)	0.08	0.17	0.21	4.48	6.48	6.14	0.52

Conclusion
The study determined the importance of SSNM practices on leaf area index and PAR interception in rice crop and its consequent effect on final grain yield. The NE^R was found better over other treatments in enhancing the growth and development of rice crop and in getting higher dividends from the crop. Hence, the Nutrient Expert based recommendation ($N_{141}P_{51}K_{75}Zn_{15}$) may be suggested as the better nutrient management practice over the state recommended practice for the farmers of this region or site.

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