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LEAF CHLOROPHYLL METER- A NON-DESTRUCTIVE METHOD FOR SCHEDULING NITROGEN IN POTATO CROP

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ABSTRACT: A leaf chlorophyll meter (SPAD 502) was used as a tool for N-fertilization in potato. SPAD value of an over fertilized plot was used as reference to application of subsequent split doses after earthing up in different treatment plots for two prevalent varieties Kufri Jyoti and Kufri Chandramukhi. In different treatments the SPAD values differed for two varieties. Among different treatments (N schedules) higher SPAD value was observed throughout in over fertilized reference plots where 125% of recommended N was applied. In tuber yield, Kufri Jyoti (36.7 t/ha) was higher than Kufri Chandramukhi (30.5 t/ha) at all N levels/treatments. Total tuber yield under different N doses ranged from 33.1(Kufri Chandramukhi) to 34.8 (Kufri Jyoti) t/ha. Among various N schedules and levels there was no significant difference in tuber yield, though, the highest yield was obtained in the treatment where 10% of recommended N was applied at 95% of reference SPAD after basal (50%) and earthing up (20%) applications followed by in over fertilized plot there by saving 20% of recommended N (36 kg/ha). This indicated that increasing the number of splits of N supplied N to the crop for longer duration to maintain the yield level of both varieties compared to over fertilized plot even at much lower N application rate. The best period to detect N deficiency in potato for corrective N fertilization was found to be on or before 45 DAP which is tuberization phase. Gross return (2.26 lakh/ha), net return (1.53 lakh/ha) and B:C ratio (3.1) was higher with Kufri Jyoti compared to Kufri Chandramukhi. Among different N treatments gross return (2.09 thousand / ha), net return (1.37 thousand/ha) and B : C (2.9) ratio were highest with 50% at planting + 20% at earthing + 10% at 95% reference value. Thus, there was 20% saving of N by splitting of N based on SPAD value.

KEYWORDS: Chlorophyll meter, nitrogen, potato varieties, SPAD

INTRODUCTION

Potato plants require relatively large amounts of N for optimum growth and tuber production. Ideally, the fertilizer requirement should meet the difference between plant need (total N uptake at high yield) and the N contribution from the soil (soil organic matter, incorporated legume crops, manures, etc.).

However, accurate prediction of soil N contribution is difficult because it varies considerably with soil type and environmental conditions (temperature, soil aeration, rainfall) which are beyond the control of growers. To ensure against such uncertainties, growers traditionally apply large amounts of N at the time of planting. A more environmentally sound and cost effective strategy to improve N-use efficiency would be to apply moderate amounts of N at planting and the remainder as side dressings, as needed, before the last cultivation at hilling. The maintenance of soil fertility was based mainly on the application of mineral fertilizers (Németh and Kádár, 1991). During the last few decades, therefore, farmers applied more nitrogen than the crop demand, and the overall nitrogen balance became positive. Restoring the nutrient supply improves the quality and quantity of yield for all agricultural crops as well (Nagy, 2006). The yield quality, macro element content and their ratios correlate with the amount of fertilizer (Poljak *et al.*, 2007). Potato fertilization (especially nitrogen fertilization)

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has repercussions on the dynamics of plant growth and the production and quality. The N concentration of plant tissues is closely correlated with the N supplying capacity of the soil. The most commonly used non invasive method is based on measurements with a chlorophyll meter device SPAD (Soil Plant Analysis Development) values of potatoes indicates ample opportunities to use these non-invasive measures to monitor the condition of vegetation in different crop growing conditions (Puiu *et al*., 2012 and Shukla *et al*., 2007) that can relate to leaf chlorophyll concentration (Goffart *et al*., 2008). A determination of the chlorophyll content thus allows the N nutrition level of the plant, and indirectly the N supplying capacity of the soil, to be estimated. Using SPAD 502 chlorophyll meter for monitoring the chlorophyll content of leaves it may notice the existence of a possible shortage of nitrogen, early enough to be corrected in time without diminishing the production (Shapiro, 2006). The SPAD readings provide a better, rapid and convenient field method to monitor and regulate the N status of potato crop through crop growth period (Singh *et al*., 2007). Assessment of crop nitrogen status throughout the growing season is indispensable in order to measure to optimize dynamic N supply (Shukla *et al*., 2007). Measurements with the SPAD 502 meter produce relative SPAD meter values that are proportional to the amount of chlorophyll present in the leaf (Qihua *et al*., 2011). The chlorophyll meter is an appropriate tool to determine the nutritional status of N content in potato crop (Giltto *et al*., 2010). Chlorophyll content in vegetation depends on soil nitrogen availability and on crop nitrogen uptake (Jongschaap *et al*., 2004). Víga *et al*., (2012) showed that the SPAD values change at every foliar level and the measurements carried out on the middle foliar level provide the closest correlation with average SPAD values of the leaf canopy. For that, they recommend making measurements at different foliar levels or on the middle foliar level to determine the average SPAD value of the potato leaf canopy. The most important limitation is that factors other than available N (variety, growing season, location) can affect plant growth and chlorophyll development and thus the SPAD values obtained (Minotti *et al*., 1994). Nitrogen deficiency can be indicated by the SPAD value with great security. It can provide a possibility for the development of an environment friendly nutritive management (Széles, 2007) by predicting the N status of various crops and determining their fertilization requirements (Bonneville and Fyles, 2006). Study has two main goals of improving knowledge of the crop's N status and to improve its utilization from soil.

MATERIALS AND METHODS

Field experiments for testing six N application schedule with two potato cultivars namely Kufri Jyoti and Kufri Chandramukhi were conducted in 2013-14 and 2014-15 at the ICAR-Central Potato Research Station, Gwalior, MP on silty clay loam soil . Situated at 26° 13′N latitude 78° 14′ East longitude and 206 m above sea level are the geographical coordinates of experimental field, Gwalior MP. Bulk density, particle density and water holding capacity of experimental soil was 1.28 g/m^3, 2.56 g/m^3 and 44.47%, respectively. Annul average rainfall in the range of 600-800 mm with low water availability in the region. Different N schedules included recommended dose of N in two splits as basal and at earthing up, over fertilization (125% of recommended N) half as basal and half at earthing up and four other treatments in which top dressing of N was done after basal (50% of recommended) and at earthing up (20% of recommended) when SPAD value reached either 90 or 95%

of that of reference over fertilized plot. Rate of top dressing in these treatments were either 10 or 20% of the recommended N. Treatment details are T_1: 125% of recommended N (half at planting and half at earthing up) over fertilized reference, T_2: Recommended N (half at planting and half at earthing up), T_3: 50% of recommended N at planting, 20% at earthing up and 10% when SPAD value reached 90% of the reference, T_4: 50% of recommended N at planting, 20% at earthing up and 20% when SPAD value reached 90% of the reference, T_5: 50% of recommended N at planting, 20% at earthing up and 10% when SPAD value reached 95% of the reference, T_6: 50% of recommended N at planting, 20% at earthing up and 20% when SPAD value reached 95% of the reference. Recommended dose of fertilizer (RDF) followed in these experiments for N, P_2O_5 and K_2O was 180, 80 and 120 kg/ha, respectively. The entire dose of N was applied through urea. The plots were located on the site of a previous potato crop with a history of recommended fertilization. Every year green manuring was done with dhaincha (*Sesbania acculeata*) prior to potato production. Initial soil testing showed that site was having available P medium (20 kg/ha), and available K high (395 kg K/ha). The phosphorus was applied in the form of single super phosphate and potassium was applied through muriate of potash and both were applied at the time of potato planting. The fertilizer was banded 5 cm away on both sides of the seed and 2.5 cm below the seed. The pH of the site was 7.4, Electrical conductivity 0.23 dS/m at 25°C and available N was 165 kg/ha.

Commercially certified seed stored at 4°C was taken out from cold store to ambient temperature of 20 - 25°C for warm-up and chitting twenty days before planting. Planting dates were first week of November during both the years. The design was a split plot with three replications. Plots consisted of 4.0 m long 7 rows with 20 cm intra row, 60 cm inter row spacing. Data were obtained from the centre five rows. Cultural practices and a combination of hilling, cultivation, pest and disease control, and irrigations were applied as required by the crop during the growing season. Non apparent growth-limiting factors were observed other than the N treatments. At the same time non-invasive measurements, for determination of relative chlorophyll content from leaf using handheld Chlorophyll Meter SPAD 502 was used to obtain readings estimating chlorophyll concentration on the fourth or fifth leaf down from the top of the plant at 34, 40, 45, 50, 60, 70, and 84 DAP. The values determined with the hand-held device SPAD 502 indicates the relative amount of chlorophyll present in the leaves. The SPAD reading of potato leaf was obtained at three locations: (a) about one-third of the leaf length from the petiole, (b) at the midpoint of leaf, and (c) about one-third of the leaf length from the apex (Lin *et al.*, 2010). Fifteen readings from each plot, were taken and averaged. Haulm uprooting was done at 90 DAP during both the years. Tubers were harvested 15-20 days after haulm cut and yield data were recorded from the five middle rows in different grades from each plot. Split plot analyses were used to identify significant variety effects and any N rate variety interactions. Analyses of variance (ANOVA) were used for testing differences in SPAD values.

RESULTS AND DISCUSSION

Growth and yield parameters: Between two varieties, significantly higher plant height (48 cm) was recorded with Kufri Jyoti compared to Kufri Chandamukhi. However, varieties did not show any significant effect on number of stem/plant and number of compound leaves/plant. Various N schedules did not show any significant effect on plant height except in treatment where 10% of recommended N was applied at 90% of reference SPAD which had significantly lower plant height (36 cm) as compared to that in the over fertilized treatment. Highest number of compound leaves (52.9) was recorded in the treatment receiving recommended dose of N which was statistically at par with that recorded at other doses/splitting of N. Larger photosynthetically active leaf surface could be important to maintain higher tuber bulking rates resulting in higher tuber yields (Bradley *et al*., 2005). Kufri Jyoti produced higher number of small size tubers (1.01 lakh/ha) than Kufri Chandramukhi, though values were statistically at par. There was no significant effect of varieties on number of medium size tubers, however, the number of large size tubers was significantly higher in Kufri Jyoti (2.23 lakh/ha) as compared to Kufri Chandramukhi. Number of crack tubers were also significantly higher with Kufri Jyoti (0.29 lakh/ha) which is its varietal character, hence, not found in Kufri Chandramukhi. As a result, accumulating all grades total number of tubers were recorded significantly higher in Kufri Jyoti (4.72 lakh/ha in) as compared to that in Kufri Chandramukhi. The two key yield components of potato are tuber numbers per unit area, and tuber size or weight. Increased yields come from achieving the optimum tuber numbers, maintaining a green leaf canopy, and increasing tuber size and weight.

Highest number of small size tubers (1.09 lakh/ha) was recorded in over fertilized plots where N was applied in two splits at 125% of recommended dose, however, the values were statistically at par with other N treatments. There was no significant effect of varying N applications rate and schedule on number of medium size tubers. Highest total number of tubers (4.48 lakh/ha) were also recorded in over fertilized reference treatment, which was significantly higher than the total number of tubers recorded in the treatment receiving recommended N 50% basal and 50% earthing up **(Table 1)**. All other treatments did not show any significant variation in tuber numbers.

Yield of different size tubers followed similar trend as that of their numbers. Kufri Jyoti gave better total tuber yield and large size tuber yield than Kufri Chandramukhi, however, Small size tuber yield (2.3 t/ha) was higher in Kufri Chandramukhi which was statistically at par with Kufri Jyoti. There was no significant effect of N applications/ splitting on yield of different size tubers, however, highest total tuber yield (34.8 t/ ha) was recorded in the treatment where 10% of recommended N was applied at 95% reference SPAD value after basal and earthing up applications. It was followed by in the treatment which was over fertilised.

Dry matter, harvest index and nutrient uptake: Higher tuber dry matter, haulm dry matter and total biological yield were recorded with Kufri Jyoti which was significantly higher than Kufri Chandramukhi **(Table 2)**. There was no significant effect of N doses/splitting on tuber and haulm dry weight yield of potato, however, the total biological yield was highest in over fertilized plots which was significantly higher from recommended treatment. Biological yield (total dry matter) increased in different treatments with increasing split of N based on SPAD and become at par with reference plot. Zebarth *et al.*, 2012 reported that split N application had no effect on crop response, and significantly reduced nitrate exposure. It shows that splitting of nitrogen reduced volatilization/leaching losses. Morier *et al.* (2015) reported that red-edge chlorophyll index was the most sensitive to potato

Table 1. Effect of nitrogen application on growth, yield attributes and yield of potato (two years mean data).

Treatments/ Varieties	Plant height (cm)	Stem/ plant	Leaves/ plant	Number of tubers ('000/ha)				Yield of tubers (t/ha)			
				Small size	Medium size	Large size	Total	Small size	Medium size	Large size	Total
Kufri Chandramukhi	32	3.4	45.6	97	148	151	396	2.3	9.8	18.4	30.5
Kufri Jyoti	48	3.5	49.2	101	149	223	472	2.0	9.9	25.7	37.6
SE±	2.5	0.3	2.7	8	5		4	0.2	0.6	1.5	0.9
CD	5.2	NS	NS	NS	17	25	20	NS	NS	3.2	1.8
				N Level/Schedule							
T_1	43	3.4	45.2	109	147	192	448	2.3	9.6	22.8	34.6
T_2	41	4.0	52.9	91	152	188	431	2.1	10.2	21.6	33.9
T_3	36	3.3	44.5	88	132	186	406	2.2	8.9	22.1	33.1
T_4	40	3.4	46.8	104	152	177	433	2.3	10.3	20.9	33.5
T_5	42	3.3	47.9	97	156	188	441	2.1	10.3	22.5	34.8
T_6	41	3.3	47.2	107	150	190	447	2.2	9.7	22.5	34.4
SE±	4	0.4	4.7	12	8	11	7	0.3	1.1	2.2	1.5
CD	NS	NS	NS	NS	30	35	35	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Effect of nitrogen application dry weight of tuber, haulm and NPK uptake of potato (two years mean data).

Treatments/Varieties	Tuber dry weight (t/ha)	Haulm dry weight (t/ha)	Biological yield t/ ha	Harvest index (%)	Nutrient uptake (kg/ha)			Economics (000/ha)		
					N	P	K	Gross return	Net return	B : C ratio
Kufri Chandramukhi	5.5	0.9	6.4	86	112	12	91	183	110	2.5
Kufri Jyoti	6.3	1.6	7.9	79	134	16	126	226	153	3.1
SE±	0.2	0.09	0.24	1.1	7	0	5	-	-	-
CD	0.4	0.19	0.49	2.3	14	1	9	-	-	-
				N Level/Schedule						
T_1	6.7	1.4	8.1	83	129	13	120	208	134	2.8
T_2	6.1	1.1	7.2	85	131	12	98	203	131	2.8
T_3	6.2	1.3	7.5	83	121	14	105	199	126	2.7
T_4	6.4	1.2	7.6	85	117	15	106	201	128	2.8
T_5	6.6	1.3	7.9	83	124	17	112	209	137	2.9
T_6	6.4	1.2	7.6	84	117	15	111	206	134	2.8
SE±	0.4	0.16	0.42	1.9	11	1	8			
CD	NS	NS	0.86	NS	NS	2	16			
Interaction	NS	NS	NS	NS	NS	NS	NS			

N content and could explain 76% of the variability in total tuber yield at 55 days after planting (DAP). There was no any significant effect of N doses/splitting on harvest index. During early growth stages, most of the dry matter is partitioned in leaves (80%) and stems (20%) (Jenkins and Mahmood, 2003). However, after onset of tuber initiation, greater proportion of dry matter is partitioned to the tubers.

As the dry matter production was higher the uptake of N, P and K was also higher in Kufri Jyoti than that in Kufri Chandramukhi. There was no any significant effect of N doses/splitting on N uptake, but the highest P uptake (17 kg/ha) was recorded in the treatment where 10% of recommended N was applied at 95% reference SPAD value after basal and earthing up applications. Highest K uptake (120 kg/ha) was recorded in over fertilized plot, which was significantly higher than recommended treatment. In other treatments where N was applied in more splits based on reference SPAD values the K uptake improved and become at par with that of over fertilized plot. It means, with increased number of splits even at lower level of N applications P and K uptake improved.

Effect of chlorophyll content (SPAD values): There were variations in the trend of changes in SPAD values between the varieties **(Table 3)**. The highest SPAD value was recorded in Kufri Jyoti (51.4) at 35 days after planting which was statistically at par with Kufri Chandramukhi (49.3). Up to 45 DAP both the varieties showed almost similar SPAD values, however, after that there was sudden drop in chlorophyll content of Kufri Jyoti 51.4 to 36.3, conversely, for Kufri Chandramukhi the decline was not so steep 49.3 to 42.0. This shows that there is need to side dress nitrogen to get optimum yield from variety Kufri Jyoti. Results of Marouani *et al.*, 2015 had showed that varieties did not present N deficiencies during the vegetative growth phase. During the tuber bulking phase to reach maximum yields, SPAD value 38.5 and 40.5 are desirable. Since this drop continues up to maturity, hence, unrecoverable reduction in tuber yield is caused due to yellowing of leaves/ reduced chlorophyll content. Application of N levels/side dressings could not improved chlorophyll contents hence, it necessitates to try N in different doses to find out most suitable time and dose for side dressings.

Economics: Gross return was higher with Kufri Jyoti (Rs 2.26 lakh/ha) compared to

Table 3. Effect of nitrogen application on chlorophyll content (SPAD values) in potato leaves.

Treatments	34 DAP	40 DAP	45 DAP	50 DAP	60 DAP	70 DAP	84 DAP
			Varieties				
Kufri Chandramukhi	49.3	47.6	48.4	43.3	42.0	42.5	43.2
Kufri Jyoti	51.4	47.6	48.6	37.1	38.0	36.3	38.5
SE±	2.7	1.4	2.7	1.7	1.7	1.7	1.8
CD(P=0.05)	NS	NS	NS	3.5	3.5	3.5	3.6
			N Level/Schedule				
T_1	53.2	49.5	52.0	43.3	42.6	38.7	43.8
T_2	48.0	46.4	48.5	41.8	40.1	39.2	39.1
T_3	51.0	45.6	48.9	38.7	40.2	40.6	38.2
T_4	54.6	47.3	49.6	38.0	41.8	40.0	41.7
T_5	45.8	48.9	46.1	41.6	39.4	40.1	43.5
T_6	49.3	48.0	46.2	37.8	35.8	34.7	39.0
SE±	4.7	2.4	2.1	3.0	2.9	35.8	3.0
CD(P=0.05)	9.8	5.0	4.4	6.1	6.1	7.2	6.3
Interaction	NS	NS	NS	NS	NS	NS	NS

T_1 125% of recommended N (half at planting and half at earthing up) over fertilized reference, Kufri Chandramukhi (Rs 1.83 lakh/ha). Similar trend was observed for net return wherein Rs 1.53 lakh/ha was recorded for Kufri Jyoti and Rs 1.10 lakh/ha for Kufri Chandrmukhi. Higher B:C ratio was also recorded for Kufri Jyoti (3.1) compared to Kufri Chandramukhi (2.5). Amongst various N schedules highest gross return was recorded with the same treatment where 10% of recommended N was applied at 95% reference SPAD value after basal and earthing up applications (Rs 2.09 lakh/ha). This treatment gave highest yield with 20% lower application of N. Due to 20% saving of N and higher yield this N scheduling gave highest net return and B:C ratio.

CONCLUSIONS

These observations made it obvious that if number of splits of N application is increased based on SPAD value, it is possible to save 10 to 20% of recommended N without compromising on yield. In the treatment where 10% of recommended N was applied when SPAD value of leaves deceased to the level of 95% of that of reference over fertilized treatment after 50 and 20% of recommended N application at planting and earthing up, respectively, there was saving of 20% N, i.e. 36 kg/ha. This treatment was highest yielder even better than over fertilized reference plots, though, non-significantly. Reaching the same level of yield with 10 to 20% less application nitrogenous fertilizer will increase the nutrient use efficiency besides making potato cultivation economically more viable and environmentally more sustainable.

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