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Madhu Bindu GS
Examination Center, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

Pratap Kumar Reddy A
Administrative Office, Acharya N. G. Ranga Agricultural University, Guntur, Andhra Pradesh, India

Suneetha Devi KB
Administrative Office, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

Padmaja G
Administrative Office, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

Corresponding Author:
Madhu Bindu GS
Examination Center, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

Plant uptake and soil availability of nutrients acknowledging irrigation scheduling, phosphorus and boron application in Lucerne

Madhu Bindu GS, Pratap Kumar Reddy A, Suneetha Devi KB and Padmaja G

Abstract
The field study conducted at College of Agriculture, Rajendranagar, Hyderabad on the response of Lucerne to irrigation scheduling, phosphorus and boron application indicated that the dry matter content and the uptake of N, P, K and B by Lucerne fodder and seed were higher with irrigation at 1.25 IW/CPE ratio. Phosphorus application @ either 80 or 120 kg P_2O_5 ha^{-1} registered higher dry matter content, nitrogen and potassium uptake by fodder. On the other hand, highest level of phosphorus @ 120 kg P_2O_5 ha^{-1} alone registered highest uptake of phosphorus and boron by fodder and seed. Application of boron @ 4 kg ha^{-1} has resulted in highest dry matter content and nutrient uptake by Lucerne fodder and seed. On the other hand, soil available nitrogen was higher when irrigations were scheduled at 0.75 IW/CPE ratio with phosphorus and boron fertilization @ 120 and 4 kg ha^{-1}.

Keywords: Plant uptake, soil availability, nutrients acknowledging irrigation scheduling, phosphorus

Introduction
Lucerne is known as 'green gold' and queen of cultivated fodder crops occupying third position in area and production after fodder Sorghum and Hybrid Napier in India. In India, it occupies an area of one m ha and provides 60 to 130 t of green forage ha^{-1}. It is grown as a farm crop in Punjab (13554 acres), western districts of Uttar Pradesh, Maharashtra (18400 acres), Gujarat (19900 acres), Madras and West Bengal (Shukla *et al*., 2004) [8]. The non-availability of quality seed hampered its cultivation in Andhra Pradesh. Lucerne is notoriously erratic in seed production and seed yield is very low (50 to 250 kg ha^{-1}). This is because of poor source-sink relationship, abscission of flower, slow pod formation and maturity, and under development of fruiting pods due to excessive vegetative growth and pod shattering. Hence no acreage is devoted for seed production of Lucerne. It has a low multiplication ratio of 15. The seed production of Lucerne is highly variable at different agro-environments, which ranged from 2-3 q ha^{-1} in Hyderabad to 0.6-1.0 q ha^{-1} in Jhansi. The potential areas identified for increased seed productivity in Lucerne are west and south-central regions of the country (Singh and Hazra, 1995b) [9]. Southern Telangana Zone of Andhra Pradesh falling under south-central region has a potential to improve Lucerne seed productivity with appropriate crop and soil management practices.

Lucerne is a highly productive crop and responds well to irrigations and needs frequent irrigations than any other forage crops. Since the foliage of Lucerne is the part of plant harvested, active vegetative growth of Lucerne can be improved only through judicious application of water throughout the growing season. Lucerne produces large quantities of biomass and hence requires large amount of nutrients. It removes 4.5-6.8 P_2O_5, 22.7-29.5 K_2O and 0.036 B kg per ton of dry matter. Being a leguminous crop, its phosphorus requirement is very high (Virender Sardana and Narwal, 1999) [12]. A five-ton biomass producing crop requires approximately 22.7 kg P_2O_5 ha^{-1}. The prior knowledge about the removal of nutrients by crop plants is imperative to apply them in sufficient quantities to harness potential yield of a crop. Phosphorous fertilization as known for its role for root growth, protein synthesis, nitrogen fixation and ultimately in stepping up the biomass yield of legume forage crops is a commendable proposition. In addition to phosphorus, boron requirement of Lucerne is also very high. Boron is essential for pollen germination and pollen tube growth during fertilization and influences seed yield. Deficiency of boron severely affected the viability of pollen grains (Dugger, 1983) [4].

Soil and foliar application of boron to Lucerne helps in increasing the seed yield. Keeping the above points in view, the study was conducted to evaluated the response of Lucerne to irrigation scheduling, phosphorus d boron application in terms of dry matter production, nutrient uptake and soil availability of nutrients.

Materials and Methods

The field experiment was conducted at Students' farm, College of Agriculture, Rajendranagar, Hyderabad, during *rabi* seasons of 2007-08 (First year) and 2008-09 (Second year). The experiment was laid out in split plot design with three replications. The treatments comprised of three irrigation levels at IW/CPE ratios of 0.75, 1.00 and 1.25 as main plots and combinations of four phosphorus levels (0, 40, 80 and 120 P_2O_5 kg ha^{-1}) and two boron levels (0 and 4 kg B ha^{-1}) as sub plots. Seeds with germination of about 90 per cent were sown @ 15 kg ha^{-1} in solid rows opened at a spacing of 30 cm. Irrigations as per the treatment were scheduled according to the cumulative pan evaporation calculated based on evaporation data obtained from Class B meteorological observatory at Rajendranagar, Hyderabad. The recommended dose of nitrogen to Lucerne (30 kg N ha^{-1}) was applied in two splits at the time of sowing and 30 DAS. Phosphorus as per treatments and recommended potash (40 kg K_2O ha^{-1}) were applied as basal. In case of boron treatment, 50% of the recommended B was applied as basal to soil and the remaining 50% was applied as 0.1% foliar spray at four stages i.e., at 35 DAS, 10 days after first cut, 10 days after second cut and at flower initiation stage. Fresh plant samples taken at each cut from one meter row length were weighed and then oven dried at 60 °C to determine their dry weights. Later on the dry matter content of each sample at each cut expressed as per cent was calculated as follows.

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight of sample}}{\text{Fresh weight of sample}} \times 100$$

Plant samples collected at first, second and third cuttings of green fodder and seed samples collected at seed harvest were analyzed for their nitrogen, phosphorus, potassium and boron contents. N, P, K and B contents in both fodder and seed were estimated by micro-kjeldhal (AOAC, 1970) [1], vanado-molybdo-phosphoric yellow colour (Jackson, 1973) [6], flame photometric (Jackson, 1967) [5] and spectrophotometric (Wolf, 1971) [13] methods, respectively. The nutrient uptake by forage and seed expressed as kg ha^{-1}, was calculated by multiplying the nutrient content with dry matter yield and seed yield, respectively.

$$\text{Nutrient uptake by forage (kg ha-1)} = \frac{\text{Nutrient content (\%) x Dry matter yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Nutrient uptake by seed (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) x Seed yield (kg ha}^{-1}\text{)}}{100}$$

Soil samples were collected during both the years before sowing and after each cut and analysed for available nitrogen, phosphorus, potassium and boron (kg ha^{-1}) by the following procedures:

Available nitrogen (kg ha^{-1}): Alkaline permanganate method (Subbaiah and Asija, 1956) [11].

Available phosphorus (kg ha^{-1}): Olsen's method using colorimeter (Olsen *et al*., 1954) [7].

Available potassium (kg ha^{-1}): Neutral ammonium acetate method using flame photometer (Jackson, 1967) [5].

Available boron (kg ha^{-1}): Hot water plate method (Berger and Truog, 1939) [2].

Results and Discussion

1. Dry matter content

Dry matter content of Lucerne in response to irrigation, phosphorus levels and boron application followed similar trend during the two years of study (Table 1). The mean of three cuts during both the years of study indicated that scheduling irrigations at 1.0 (I_2) and 1.25 (I_3) IW/CPE ratios being at par registered higher dry matter contents over I_1 (0.75 IW/CPE ratio). Whereas among the phosphorus levels, 80 (P_2) and 120 (P_3) kg P_2O_5 ha^{-1} being at par reported higher dry matter content over the other levels (0 and 40 kg P_2O_5 ha^{-1}) during first and second year of the study (Table 1). However, the effect of boron was visualized only during the second year of study during which boron application @ 4 kg ha^{-1} increased the dry matter content of Lucerne to the maximum (21.09 kg ha^{-1}) in comparison to no boron (20.15 kg ha^{-1}). Taller plants and higher leaf weight of Lucerne in I_3 and I_2 treatments had resulted in their equivalent performance with respect to mean dry matter content over the cuts. Higher stem weight added up to above characters at higher levels of phosphorus might have attributed to higher dry matter contents in P_2 and P_3 during both the years of study. On the other hand, boron seems to have inconspicuous effect on dry matter content of the plant as its effect was not consistent during both the years of study.

Table 1: Dry matter content (%) of Lucerne as influenced by irrigation, phosphorus and boron levels during two years of study (Mean of 3 cuts)

Treatments	I year	II year
Irrigation levels		
I_1 - 0.75 IW/CPE	16.78	18.24
I_2 - 1.00 IW/CPE	21.42	21.34
I_3 - 1.25 IW/CPE	22.76	22.27
SEm±	0.49	0.44
CD (P=0.05)	1.36	1.23
Phosphorus levels		
P_0 - 0 kg P_2O_5 ha^{-1}	18.56	18.46
P_1 - 40 kg P_2O_5 ha^{-1}	20.08	20.16
P_2 - 80 kg P_2O_5 ha^{-1}	21.56	22.10
P_3 - 120 kg P_2O_5 ha^{-1}	21.08	21.75
SEm±	0.74	0.35
CD (P=0.05)	1.50	0.71
Boron levels		
B_0 - 0 kg B ha^{-1}	20.00	20.15
B_1 - 4 kg B ha^{-1}	20.63	21.09
SEm±	0.52	0.25
CD (P=0.05)	NS	0.51

2. Nutrient uptake by Lucerne forage and seed

2.1 In response to irrigation scheduling

Nitrogen uptake of Lucerne was significantly influenced by irrigation, phosphorus and boron levels during both the years (Table 2). Total nitrogen uptake of Lucerne was comparable and highest for irrigations scheduled at 1.0 (I_2) and 1.25 (I_3) IW/CPE ratios during the first year of study. While in the subsequent year the total N uptake of 3 cuts was highest at 1.25 (I_3) IW/CPE ratios. High effective rainfall during the crop growing season in first year had supplemented irrigation and hence irrigation at 1.0 IW/CPE ratio (I_2) was sufficient enough to maintain optimum soil moisture for easy availability of nitrogen for plant extraction. Therefore, the crop irrigated at high frequency (1.25 IW/CPE ratio) did not vary from I_2 with regards to total plant nitrogen uptake. However in the second year, I_3 alone has achieved optimum soil water balance than I_2 and I_1 as irrigation was the major source of soil moisture supply than rainfall which henceforth reflected in higher total nitrogen uptake with I_3 over the latter treatments.

Mobility of soil phosphorus to the plant root surface is favored under wet regimes. As irrigation at 1.25 IW/CPE ratio (I_3) through more number of irrigations at shorter intervals has maintained moist conditions in the soil throughout the crop growing season, the phosphorus was readily taken by the plant in higher quantity than irrigation at either 1.0 (I_2) or 0.75 (I_1) IW/CPE ratio in both the years (Table 2). Increase in phosphorus content and dry fodder yield of Lucerne with subsequent plant removal due to increase in moisture supply from 0.75 to 1.25 IW/CPE ratio was also reported by Solanki and Patel (2000).

Similar to phosphorus uptake, potassium uptake was also higher with irrigation at 1.25 IW/CPE ratio (I_3) than at 1.0 (I_2) or 0.75 (I_1) IW/CPE ratios after three cuts in both the years. Irrigation at 1.0 IW/CPE ratio (I_2) though was found effective in maintaining soil moisture equivalently sufficient as that in I_3 for higher potassium removal by the plant during first year, its accomplishment was not consistent in the next year. Hence, irrigation scheduled at 1.25 IW/CPE ratio with desirable soil water balance due to higher water supply throughout the crop growing period has improved plant potassium uptake to a higher level at each cut which in turn resulted in higher total potassium uptake over the cuts in the first year (Table 2). The outstanding performance of the crop at higher level of irrigation (I_3) was concurrent in the second year.

Irrigation also had profound influence on boron mobility and hence boron uptake by Lucerne (Table 2). Favorably wet regime of the soil throughout the cropping season due to irrigations at 1.25 IW/CPE ratio (I_3) has improved boron mobility to the root surface resulting in its increased uptake over the lower levels of irrigation (1.0 and 0.75 IW/CPE ratio).

Relatively higher uptake of nitrogen, phosphorus, potassium and boron by Lucerne plant under 1.25 IW/CPE ratio (I_3) has inevitably caused translocation of higher amount of these nutrients to the seed at seed development stage which was obvious with higher N, P, K and B uptake values of the seed (Table 3).

2.2 In response to phosphorus levels

Phosphorus levels also had significant effect on nitrogen uptake of Lucerne which improved to a higher level due to phosphorus fertilization @ 80 (P_2) and 120 (P_3) kg P_2O_5 ha^{-1} which being comparable and proved superior to their lower levels (0 and 40 kg P_2O_5 ha^{-1}) during both the years. The total of three cuts indicated that no phosphorus application (P_0) has resulted in lowest nitrogen uptake than 40, 80 and 120 kg P_2O_5 ha^{-1}. Boron also had remarkable effect on nitrogen uptake of Lucerne which when applied @ 4 kg ha^{-1} has caused highest uptake of nitrogen as compared to no boron treatment (B_0) during both the years of study (Table 2).

It is an established fact that phosphorus application has a synergistic effect on uptake of nutrients viz., nitrogen, phosphorus, potassium and boron. In congruity, the nutrient uptake by both plant and seed of Lucerne increased with increase in phosphorus levels from 0 to 120 kg P_2O_5 ha^{-1} during both the years of experimentation (Table 2). Phosphorus application @ 80 (P_2) and 120 (P_3) kg ha^{-1} being at par registered higher uptake of nitrogen and potassium at each cut during both the years. Improved microbial activity due to increased nodulation and increased translocation of nutrients due to root proliferation at higher levels of phosphorus (80 and 120 kg P_2O_5 ha^{-1}) might have contributed to higher nitrogen and potassium contents, respectively in the plant tissue which further being complemented with higher dry fodder yields has resulted in higher nitrogen and potassium uptake values.

Table 2: N, P, K and B uptake (kg ha-1) by Lucerne as influenced by irrigation, phosphorus and boron levels during two years of study (Total of three cuts)

Treatments	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		B uptake (kg ha^{-1})	
	I year	II year	I year	II year	I year	II year	I year	II year
Irrigation levels								
I_1 - 0.75 IW/CPE	76.98	93.26	7.63	10.87	76.46	94.72	25.90	34.06
I_2 - 1.00 IW/CPE	134.60	147.32	16.27	19.40	140.93	156.53	58.77	69.52
I_3 - 1.25 IW/CPE	151.85	164.07	21.67	24.40	166.61	186.00	85.93	99.20
SEm±	7.64	4.84	0.57	0.67	9.29	6.22	5.72	4.83
CD (P=0.05)	21.22	13.45	1.59	1.86	25.79	17.28	15.88	13.40
Phosphorus levels								
P_0 - 0 kg P_2O_5 ha^{-1}	77.15	86.33	7.35	8.31	83.16	96.09	22.88	30.24
P_1 - 40 kg P_2O_5 ha^{-1}	108.62	119.24	12.50	14.24	116.25	130.53	44.63	54.30
P_2 - 80 kg P_2O_5 ha^{-1}	149.12	165.35	19.05	22.71	157.12	178.06	73.89	86.95
P_3 - 120 kg P_2O_5 ha^{-1}	149.67	168.62	21.86	27.63	155.48	178.32	86.07	98.88
SEm±	5.12	3.41	0.71	0.30	5.44	3.66	3.15	2.55
CD (P=0.05)	10.33	6.88	1.43	0.61	10.98	7.39	6.35	5.15
Boron levels								
B_0 - 0 kg B ha^{-1}	111.63	123.75	13.82	16.55	118.07	133.90	48.40	57.30
B_1 - 4 kg B ha^{-1}	130.65	146.01	16.56	19.89	137.94	157.60	65.33	77.88
SEm±	3.62	2.41	0.50	0.21	3.85	2.59	2.22	1.80
CD (P=0.05)	7.31	4.87	1.01	0.43	7.76	5.22	4.49	3.64

Table 3: N, P, K (kg ha^{-1}) and B (g ha^{-1}) uptake by Lucerne seed as influenced by irrigation, phosphorus and boron levels during two years of study

Treatments	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		B uptake (kg ha^{-1})	
	I year	II year	I year	II year	I year	II year	I year	II year
Irrigation levels								
I_1 - 0.75 IW/CPE	10.60	11.85	1.42	1.68	9.94	10.69	2.32	2.74
I_2 - 1.00 IW/CPE	11.29	12.14	1.79	2.02	11.13	11.56	3.45	3.99
I_3 - 1.25 IW/CPE	11.71	13.69	2.11	2.48	12.06	13.78	4.91	6.01
SEm±	0.10	0.28	0.10	0.05	0.10	0.23	0.16	0.20
CD (P=0.05)	0.28	0.79	0.26	0.15	0.29	0.64	0.44	0.55
Phosphorus levels								
P_0 - 0 kg P_2O_5 ha^{-1}	8.83	9.84	1.15	1.24	8.84	9.55	1.44	1.94
P_1 - 40 kg P_2O_5 ha^{-1}	10.23	11.47	1.52	1.69	10.24	11.11	2.80	3.37
P_2 - 80 kg P_2O_5 ha^{-1}	12.76	14.25	2.01	2.44	12.48	13.59	4.38	5.19
P_3 - 120 kg P_2O_5 ha^{-1}	12.99	14.67	2.39	2.87	12.62	13.79	5.60	6.49
SEm±	0.23	0.15	0.04	0.03	0.22	0.14	0.13	0.13
CD (P=0.05)	0.47	0.31	0.08	0.07	0.44	0.28	0.26	0.27
Boron levels								
B_0 - 0 kg B ha^{-1}	10.69	11.92	1.68	1.95	10.55	11.40	3.02	3.62
B_1 - 4 kg B ha^{-1}	11.71	13.19	1.86	2.17	11.54	12.62	4.09	4.87
SEm±	0.17	0.11	0.03	0.02	0.15	0.10	0.09	0.09
CD (P=0.05)	0.33	0.22	0.06	0.05	0.31	0.20	0.18	0.19

On the other note, plant extraction of phosphorus and boron increased with each increment of phosphorus level recording maximum values at 120 kg P_2O_5 ha^{-1} (P_3) during both the years (Table 2). Increased availability of phosphorus from the labile pool due to soil addition of phosphorus at highest dose (120 kg P_2O_5 ha^{-1}) might had eventually increased its content in plant and ultimately its uptake. Furthermore, increased microbial activity at 120 kg P_2O_5 ha^{-1} (P_3) might had caused the release of boron from parent materials which thereafter was easily extracted by highly proliferated roots resulting in its increased uptake.

The seed of Lucerne also exhibited higher uptake values of nitrogen, phosphorus, potassium and boron due to phosphorus fertilization @ 120 kg ha^{-1} than the other levels (0, 40 and 80 kg P_2O_5 ha^{-1}) (Table 3). Apportioning of greater amount of the above nutrients extracted by the plants at seed development stage might had increased their contents in the seed which eventually reflected in higher uptake values.

2.3 In response to boron application

Both plant and seed uptake of nitrogen, phosphorus, potassium and boron reported considerable improvement hither to boron application @ 4 kg ha^{-1} (B_1) over no boron treatment (B_0) (Table 2). Soil supply of boron increased its availability to the root surface which up on plant absorption in association with phosphorus might had strengthened the structural frame work of the plant by improving the conducting tissues resulting in higher uptake of nutrients. Nitrogen, phosphorus and potassium being highly mobile might have readily translocated to the seed at seed development stage in higher amounts owing to higher plant uptake. On the other note, boron is immobile in Lucerne and the major constraint for its movement to the seed is less developed xylem connection between seed and mother tissue (Dell *et al*., 2002) [3]. Foliar application of boron at 10 days after each cut apart from soil application therefore might have met the need of boron at flowering and seed development stage which eventually exhibited in higher values of seed boron uptake (Table 3).

3. Soil nutrient status

Irrigation, phosphorus and boron levels had significant influence on soil available nitrogen status after three cuts during both the years. The available nitrogen, phosphorus, potassium and boron estimated in the soil after three cuts were higher due to irrigations at 0.75 IW/CPE ratio (I_1), phosphorus and boron fertilization @ 120 (P_3) and 4 (B_1) kg ha^{-1} among the respective treatment levels (Table 4).

The crop depleted the soil nitrogen, phosphorus, potassium and boron with increasing levels of irrigation and the decrease was consistent after each cut in both the years. Higher uptake of nutrients by plant and seed at 1.25 IW/CPE ratio (I_3) has caused depletion of soil nutrient pool resulting in lowest soil available nutrient status. On the other hand, removal of lowest amount of nutrients by the plant and seed under 0.75 IW/CPE ratio (I_1) has replenished the soil with higher amount of nitrogen, phosphorus, potassium and boron contents at the end of the experiment. On the other hand, availability of higher nitrogen, phosphorus, potassium and boron in the soil after three cuts in P_3 (120 kg P_2O_5 ha^{-1}) indicated that in spite of higher plant removal of N, P, K and B due to application of 120 kg P_2O_5 ha^{-1}, the soil has maintained sufficient quantities of the above nutrients for soil replenishment. While, boron application seems to have complimented irrigation and phosphorus levels in replenishing the soil nutrient pool as nitrogen, phosphorus, potassium and boron even after their removal at a higher rate by the plant had been retained in the soil in higher amounts than the ‘no boron’ treatment (B_0).

Table 4: Soil nutrient status (kg ha-1) of Lucerne as influenced by irrigation, phosphorus and boron levels during the two years of study

Treatments	N		P		K		B	
	I year	II year	I year	II year	I year	II year	I year	II year
Irrigation levels								
I_1 - 0.75 IW/CPE	166.2	150.7	31.0	24.6	403.9	427.7	1.18	1.07
I_2 - 1.00 IW/CPE	144.3	125.8	27.4	20.8	387.4	409.9	0.91	0.78
I_3 - 1.25 IW/CPE	134.1	114.7	25.9	18.8	369.7	390.2	0.63	0.50
SEm±	2.7	2.7	0.4	0.3	2.8	3.1	0.05	0.05
CD (P=0.05)	7.4	7.4	1.2	0.8	7.8	8.5	0.12	0.12
Phosphorus levels								
P_0 - 0 kg P_2O_5 ha^{-1}	101.0	83.2	14.6	7.8	335.2	357.5	0.49	0.42
P_1 - 40 kg P_2O_5 ha^{-1}	138.1	120.3	22.1	15.4	368.3	390.6	0.81	0.68
P_2 - 80 kg P_2O_5 ha^{-1}	164.3	146.5	31.5	24.8	406.7	428.9	1.01	0.89
P_3 - 120 kg P_2O_5 ha^{-1}	189.4	171.6	44.2	37.5	437.8	460.1	1.32	1.13
SEm±	2.4	2.4	0.8	0.8	2.8	2.8	0.05	0.05
CD (P=0.05)	4.9	4.9	1.7	1.6	5.7	5.7	0.10	0.10
Boron levels								
B_0 - 0 kg B ha^{-1}	140.4	122.6	25.8	19.1	382.1	404.3	0.40	0.33
B_1 - 4 kg B ha^{-1}	156.0	138.2	30.4	23.7	391.9	414.2	1.54	1.23
SEm±	1.7	1.7	0.6	0.6	2.0	2.0	0.04	0.04
CD (P=0.05)	3.5	3.5	1.2	1.2	4.0	4.0	0.07	0.07

Conclusion

Form results of the study it can be concluded that scheduling irrigation at 1.25 IW/CPE ratio with 80 and 4 kg ha^{-1} of phosphorus and boron, respectively to lucerne would be best to achieve higher plant and seed nutrient uptake owing to higher dry matter contents.

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