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Study on crop water use in lucerne in response to irrigation scheduling, phosphorus, and boron application

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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 consumptive use of water (I year: 116.3 cm & II year: 128.9 cm) and the corresponding crop coefficients at different crop growth sub periods were high when the crop was irrigated at 1.25 IW/CPE ratio. The moisture extraction from 0 – 30 cm soil depth was also highest (I year: 67.8% and II year: 66.8%) with this treatment. Conversely, extraction of soil moisture from 30 – 60 cm soil depth was highest with 0.75 IW/CPE ratio with highest water use efficiency (I year: 27.2 and II year: 24.5 kg ha-mm^{-1}).

Keywords: Boron, consumptive use, crop coefficients, irrigation scheduling, moisture extraction pattern, phosphorus, water use efficiency

Introduction

The area under cultivated fodders in India is estimated to be 8.4 m ha as against the suggested allocation of at least 10 per cent of the cultivated area i.e., 14.7 m ha. Among the cultivated fodders, farmers prefer non-leguminous crops (both seasonal and perennial crops) *viz*., multicut Sorghums, Maize, Hybrid Napier etc., to obtain higher tonnage of biomass in order to meet the energy requirement of livestock. However, for sustained milk and meat production, and to provide for the protein and fat requirements of large and small animals, and also to cut down the costs on concentrate feeds, it is necessary to supplement the green and dry fodder with legumes. Among the seasonal legumes, Berseem is an important crop of North India extensively cultivated during winter. In South India, seasonal legumes are grown as per local requirements. Crops like Cowpea, Lablab, Sun hemp, Pillipesara are grown in localized pockets as rotational crops or inter crops. In order to provide leguminous green fodder continuously throughout the year, perennial legumes are to be cultivated and the fodder crop ideal for such a situation is Lucerne or alfalfa (*Medicago sativa* L.).

However, the non-availability of quality seed hampered its cultivation in Telangana. 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. The potential areas identified for increased seed productivity in Lucerne are west and south-central regions of the country (Singh and Hazra, 1995) [15]. The Southern Telangana Zone of Telangana falling under south-central region has a potential to improve Lucerne seed productivity with appropriate crop and soil management practices. Aiming the enhancement in seed productivity of lucerne in Telangana, the present experiment was framed to optimize irrigation requirement, phosphorus and boron requirement keeping in view of the findings of Oveyannikov (1973) [10] and Dugger (1983) [4]. During the course of experimentation an effort has been made to understand the crop water use in terms of consumptive use, crop coefficients, water use efficiency and moisture extraction pattern of lucerne in response to irrigation scheduling, phosphorus and boron application at different crop growth sub-periods and cuts.

Materials and Methods

The field experiment was conducted at Students' farm, College of Agriculture, Rajendranagar, Hyderabad, during *rabi* seasons of 2007-08 (I year) and 2008-09 (II 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. During the experimentation, the water use of lucerne in response to irrigation scheduling, phosphorus and boron application was estimated by measuring the consumptive use, crop coefficients, water use efficiency and moisture extraction of lucerne during crop growth sub-periods, cuts and experimentation years. The procedures followed for the estimation of above parameters is given below.

Crop evapotranspiration

For the estimation of crop evapotranspiration (ETa), the crop period was divided into number of water periods, first water period begin with the date of sowing and ended with the day prior to the first application of water or concurrence of rainfall; second water period started on the next day and ended with the day prior to rewetting and so on. The soil moisture was measured gravimetrically in each 15 cm soil layer up to 60 cm of effective root zone depth. The procedure used for estimation of crop ETa in Lucerne was as follows (Praveen Rao, 1993) [12].

$$\text{Crop ETa (cm)} = \sum_{i=1}^{i=n} \frac{M_1 i - M_2 i}{10} \cdot pbi \cdot Di$$

in which,

ETa = Crop evapotranspiration from the effective root zone depth within one irrigation cycle.

n = Number of soil layers sampled in the root zone depth.

M_1i = Mass water percentage measured 24 hours after n^{th} irrigation in i^{th} layer.

M_2i = Mass water percentage one day before the n^{th} irrigation in the i^{th} layer.

pbi = Bulk density of the soil in the i^{th} layer.

i = is the integer representing soil layer.

Σ = represents summation.

Di = Depth of soil layer in cm.

Seasonal evapotranspiration was determined by summing up ETa values of all the irrigation cycles.

Water use efficiency (WUE)

Water use efficiency is the ratio of economic yield (Green fodder) to the amount of water used by the crop in ETa.

$$\text{WUE (kg ha-mm}^{-1}) = \frac{\text{Green fodder yield (kg ha}^{-1})}{\text{Total ETa (mm)}}$$

Estimation of reference crop evapotranspiration

Reference crop ET (ETo) was determined by pan evaporation method. ETo based on pan evaporation method as outlined by Sankara Reddy and Yellamanda Reddy (2003) was formulated as –

$$\text{ETo} = \frac{\text{Crop ET (Eta)}}{\text{kc}}$$

Where,

kc – Crop coefficient.

ETa – Crop evapotranspiration.

Crop coefficients

Doorenbos and Pruitt (1977) [3] defined crop coefficient (kc) as the "ratio between crop evapotranspiration (ETa) and the reference crop ET (ETo) when the crop is grown under optimum conditions."

A plot of the crop coefficient values as a function of time is known as crop curve. For estimation of kc values, the crop growth period in Lucerne was divided into germination (15 DAS), establishment (21-30 DAS) and growth (27-38 DAS) during first cutting, regeneration (7 DAC) and growth (21-31 DAC) during second cutting and regeneration (7 DAC), growth (24 DAC), flowering (20 DAC), seed development (25 DAC) and seed maturity (9 DAC) when the crop was left for seed production. The crop evapotranspiration (ETa) was estimated as per the procedures outlined in estimation of ETo and kc values were calculated by the following expression.

$$\text{kc} = \frac{\text{Crop Eta}}{\text{ETo}}$$

Soil moisture extraction pattern

Soil moisture extraction pattern (SME) refers to the amount of soil moisture expressed as a percentage extracted by the plant roots from each layer of the effective crop root zone depth (60 cm) during the crop growing season. Thus, the seasonal crop ETa values obtained for each layer were expressed as a percentage of seasonal ETa from the entire root zone depth in a given treatment and the moisture extraction curves were constructed. The summation of soil moisture extraction in all the soil layers in the effective root zone depth gives the total extraction (100%) as given below:

$$SME_t = SME_1 + SME_2 + SME_3 + SME_4$$

Where,

SME_t = Soil moisture extraction from 0–60 cm soil depth.

SME_1 = Soil moisture extraction from 0–15 cm soil depth.

SME_2 = Soil moisture extraction from 15–30 cm soil depth.

SME_3 = Soil moisture extraction from 30–45 cm soil depth.

SME_4 = Soil moisture extraction from 45–60 cm soil depth.

Results and Discussion

Crop evapotranspiration (cm)

The crop evapotranspiration during various crop growth sub-periods from germination to seed maturity was maximum at 1.25 IW/CPE ratio (I_3) during both the years. There was a marked increase in crop evapotranspiration at active crop growth stage at both the cuts in both the years of study. However, when the crop was left for seed production during III cut, the crop evapotranspiration varied conspicuously at different growth stages among the irrigation treatments. Irrigations scheduled at 0.75 (I_1) IW/CPE ratio at III cut evidently increased the crop evapotranspiration during active crop growth stage than the regeneration stage, but again it decreased at flowering stage which later on showed a slight increase towards the seed development stage. These variations in crop evapotranspiration on the other hand, were not noted when the crop was irrigated at 1.0 IW/CPE ratio (I_2) which increased the crop evapotranspiration gradually up to seed development stage during both the years. Irrigation at 1.25 IW/CPE ratio (I_3) increased the crop evapotranspiration up to flowering stage with maximum values of 23.32 (I year) and 23.78 (II year) cm and then decreased at seed development stage in both the years (Table 1 and 2). The total consumptive use of water during both the years of study was highest (I year: 116.3 cm & II year: 128.9 cm) when Lucerne was irrigated at 1.25 IW/CPE ratio (I_3). Provision of favorable soil water balance due to frequent irrigations in I_3 might had resulted in vigorous crop growth and thus more consumptive water use. On the other note, the crop irrigated at 0.75 IW/CPE ratio (I_1) has consumed less amount of water (I year: 60.1 cm & II year: 71.3 cm) due to drying up of soil surface causing adverse effect on evaporation resulting in less water losses and low transpiration rate of the plants. These findings are in accordance with those reported by Sampath Kumar (1977) [13], Keshkar *et al*. (1991) [6], Cheema *et al*. (1977) [1], Khot *et al*. (1997)) [7].

Each incremental dose of phosphorus from 0 to 120 kg P_2O_5 ha^{-1} increased the crop evapotranspiration to a marginal extent at all the stages during both years. At any crop growth stage during both the years, crop water use was lowest when no phosphorus was applied while it was highest when phosphorus was applied at a highest rate i.e., at 120 kg P_2O_5 ha^{-1} (P_3). Phosphorus fertilization @ 120 kg P_2O_5 ha^{-1} has caused a marginal increase in consumptive use of the crop to an extent of 1.24 to 1.38 per cent over no phosphorus application. During both I and II cuttings, consumptive use of water was highest at active crop growth stage. Whereas, it increased gradually up to flowering stage and thereafter decreased towards maturity when the crop was left for seed production in both the years. Application of phosphorus through increased root proliferation might have resulted in better absorption of soil moisture and nutrients causing vigorous plant growth and hence greater canopy cover.

On the other hand, boron application @ 4 kg ha^{-1} reported marginally higher values of crop evapotranspiration over no boron treatment (B_0) at each crop growth stage (Table 1 and 2).

Table 1: Crop Evapotranspiration (cm) of Lucerne as influenced by irrigation, phosphorus and boron levels at different crop growth sub-periods during I year of the experimentation

Treatments	I Cut			II Cut		III Cut				Total Crop Growth Period (0-193 Days)
	Germination (0-15 DAS)	Establishment (16-39 DAS)	Active Crop Growth (40-77 DAS)	Regeneration (78-84 DAS)	Active Crop Growth (85-115 DAS)	Regeneration (116-122 DAS)	Active Crop Growth (123-146 DAS)	Flowering (147-167 DAS)	Seed development (168-193 DAS)	
Irrigation Levels										
I_1 - 0.75 IW/CPE	1.27	3.68	13.08	3.11	6.27	3.16	11.32	7.32	10.88	60.10
I_2 - 1.00 IW/CPE	1.46	7.65	13.86	3.26	13.08	3.39	11.35	15.23	16.59	85.88
I_3 - 1.25 IW/CPE	1.61	7.94	21.84	3.53	19.76	3.56	17.90	23.32	16.80	116.26
Phosphorus levels										
P_0 - 0 kg P_2O_5 ha^{-1}	1.38	6.36	16.20	3.24	12.98	3.31	13.46	15.23	14.69	86.85
P_1 - 40 kg P_2O_5 ha^{-1}	1.43	6.41	16.24	3.28	13.02	3.35	13.51	15.27	14.74	87.24
P_2 - 80 kg P_2O_5 ha^{-1}	1.47	6.45	16.28	3.32	13.06	3.39	13.55	15.31	14.78	87.61
P_3 - 120 kg P_2O_5 ha^{-1}	1.51	6.48	16.32	3.36	13.10	3.43	13.58	15.35	14.81	87.94
Boron Levels										
B_0 - 0 kg B ha^{-1}	1.44	6.42	16.25	3.29	13.03	3.36	13.51	15.28	14.75	87.33
B_1 - 4 kg B ha^{-1}	1.45	6.43	16.27	3.31	13.05	3.38	13.53	15.30	14.76	87.49

Table 2: Crop Evapotranspiration (cm) of Lucerne as influenced by irrigation, phosphorus and boron levels at different crop growth sub-periods during the II year of experimentation

Treatments	I Cut			II Cut		III Cut				Total Crop Growth Period (0-199 Days)
	Germination (0-15 DAS)	Establishment (16-46 DAS)	Active Crop Growth (47-85 DAS)	Regeneration (86-92 DAS)	Active Crop Growth (93-121 DAS)	Regeneration (122-128 DAS)	Active Crop Growth (129-152 DAS)	Flowering (153-173 DAS)	Seed development (174-199 DAS)	
Irrigation Levels										
I_1 - 0.75 IW/CPE	1.29	7.37	13.11	3.13	6.29	3.17	11.34	14.66	10.91	71.28
I_2 - 1.00 IW/CPE	1.48	11.54	13.90	3.28	13.12	3.41	17.62	15.28	16.65	96.27
I_3 - 1.25 IW/CPE	1.63	15.96	14.61	3.54	19.82	3.57	23.95	23.38	22.48	128.91
Phosphorus levels										
P_0 - 0 kg P_2O_5 ha^{-1}	1.40	11.54	13.79	3.26	12.99	3.32	17.55	17.69	16.59	98.11
P_1 - 40 kg P_2O_5 ha^{-1}	1.45	11.59	13.84	3.30	13.05	3.36	17.61	17.74	16.65	98.60
P_2 - 80 kg P_2O_5 ha^{-1}	1.49	11.65	13.90	3.34	13.11	3.40	17.67	17.80	16.71	99.07

P_3 - 120 kg P_2O_5 ha^{-1}	1.53	11.70	13.95	3.38	13.15	3.44	17.71	17.85	16.76	99.48
Boron Levels										
B_0 - 0 kg B ha^{-1}	1.46	11.61	13.86	3.31	13.06	3.37	17.62	17.76	16.66	98.71
B_1 - 4 kg B ha^{-1}	1.48	11.63	13.88	3.33	13.09	3.39	17.65	17.78	16.69	98.92

Crop coefficients (kc)

The influence of irrigation treatments on crop coefficient (kc) values was noteworthy, while both phosphorus and boron treatments varied the crop coefficients to a marginal extent. On the other side, the kc values in all the treatments showed a systematic pattern i.e., they were initially low at regeneration stage which increased with crop age up to flowering through active crop growth stage and decreased towards the seed development stage (Table 3 and 4).

Irrigations scheduled at 1.25 IW/CPE ratio (I_3) registered higher kc values at all the crop growth sub-periods. The highest kc value of 3.425 in the first and 1.933 in the second years were registered due to I_3 during the flowering stage. The crop coefficient value for the total crop growth period due to irrigations at higher frequency (I_3) was noticeably greater (I year: 0.969 and II year: 0.934) than those recorded due to less frequent irrigations at 0.75 IW/CPE ratio. The Kc values at any irrigation level exhibited discernible trend with crop ontogeny. Initially at germination and establishment stages, the Kc values were low due to incomplete canopy cover reflecting that most of the water loss may constitute evaporation from bare soil. Similar situation existed after every cut during regeneration stage. With advancement of crop age, the Kc values increased up to flowering stage reflecting the increased water loss due to increased transpiring surface as a consequence of rapid leaf development. Over the penultimate crop growth sub period of seed development and towards maturity, the Kc values decreased due to leaf senescence and partly due to reduced leaf activity. The higher Kc values with 1.25 IW/CPE ratio (I_3) during both the years was due to increased water loss through transpiration corresponding to full canopy cover resulted from vigorous plant growth and higher plant stand as compared to irrigations at 1.0 (I_2) and 0.75 (I_1) IW/CPE ratios.

Phosphorus and boron application increased the kc values over no phosphorus (P_0) and no boron (B_0) treatments, respectively. The Kc values estimated at different crop growth sub periods correspondingly represented the crop water use with higher values due to 120 kg P_2O_5 ha^{-1} than the remaining levels (0, 40 and 80 kg P_2O_5 ha^{-1}). Relatively, each higher level of phosphorus application increased the kc value (Table 3 and 4) over its lower level in both years. The highest kc value was registered when the crop was supplied with 120 kg P_2O_5 ha^{-1} (P_3) in both years and it varied from 1.074 to 1.204. Similarly, boron application @ 4 kg ha^{-1} (B_1) in the first and second years increased the kc values in the range of 1.068 to 1.198 over no boron treatment (B_0).

Table 3: Crop Co-efficients (k_c) of Lucerne as influenced by irrigation, phosphorus and boron levels at different crop growth sub-periods during the I year of experimentation

Treatments	I Cut			II Cut		III Cut				Total Crop Growth Period (0-193 Days)
	Germination (0-15 DAS)	Establishment (16-39 DAS)	Active Crop Growth (40-77 DAS)	Regeneration (78-84 DAS)	Active Crop Growth (85-115 DAS)	Regeneration (116-122 DAS)	Active Crop Growth (123-146 DAS)	Flowering (147-167 DAS)	Seed development (168-193 DAS)	
Irrigation Levels										
I_1 - 0.75 IW/CPE	0.233	0.391	0.981	0.895	1.012	0.857	1.114	1.275	0.768	0.835
I_2 - 1.00 IW/CPE	0.268	0.928	1.040	1.053	1.293	0.919	1.418	2.238	1.172	0.895
I_3 - 1.25 IW/CPE	0.295	0.963	1.626	1.071	1.578	0.965	2.235	3.425	1.287	0.969
Phosphorus levels										
P_0 - 0 kg P_2O_5 ha^{-1}	0.253	0.737	1.210	0.984	1.350	0.897	1.543	2.360	1.066	1.189
P_1 - 40 kg P_2O_5 ha^{-1}	0.262	0.742	1.214	0.997	1.354	0.908	1.548	2.367	1.069	1.195
P_2 - 80 kg P_2O_5 ha^{-1}	0.270	0.746	1.217	1.010	1.358	0.920	1.553	2.373	1.072	1.200
P_3 - 120 kg P_2O_5 ha^{-1}	0.277	0.751	1.219	1.021	1.362	0.930	1.557	2.379	1.074	1.204
Boron Levels										
B_0 - 0 kg B ha^{-1}	0.264	0.743	1.214	1.000	1.355	0.911	1.549	2.369	1.070	1.196
B_1 - 4 kg B ha^{-1}	0.267	0.745	1.216	1.006	1.357	0.916	1.551	2.372	1.071	1.198
Eto (cm)										
I_1 - 0.75 IW/CPE	5.44	9.42	13.33	3.48	6.20	3.69	10.16	5.74	14.16	71.61
I_2 - 1.00 IW/CPE	5.44	8.25	13.39	3.10	10.12	3.69	8.01	6.81	14.16	72.96
I_3 - 1.25 IW/CPE	5.44	8.25	13.43	3.30	12.52	3.69	8.01	6.81	13.05	74.49

Table 4: Crop Co-efficients (k_c) of Lucerne as influenced by irrigation, phosphorus and boron levels at different crop growth sub-periods during the II year of experimentation

Treatments	I Cut			II Cut		III Cut				Total Crop Growth Period (0-199 Days)
	Germination (0-15 DAS)	Establishment (16-46 DAS)	Active Crop Growth (47-85 DAS)	Regeneration (86-92 DAS)	Active Crop Growth (93-121 DAS)	Regeneration (122-128 DAS)	Active Crop Growth (129-152 DAS)	Flowering (153-173 DAS)	Seed development (174-199 DAS)	
Irrigation Levels										
I_1 - 0.75 IW/CPE	0.155	0.545	0.830	0.955	1.102	0.843	0.851	1.169	0.811	0.780
I_2 - 1.00 IW/CPE	0.178	0.853	1.017	1.086	1.209	0.931	1.332	1.406	1.080	1.040
I_3 - 1.25 IW/CPE	0.196	1.180	1.285	1.317	1.472	0.991	1.815	1.933	1.444	1.374
Phosphorus levels										
P_0 - 0 kg P_2O_5 ha^{-1}	0.168	0.853	1.013	1.087	1.229	0.904	1.325	1.495	1.120	1.060
P_1 - 40 kg P_2O_5 ha^{-1}	0.174	0.858	1.017	1.101	1.234	0.916	1.329	1.500	1.124	1.065
P_2 - 80 kg P_2O_5 ha^{-1}	0.179	0.862	1.021	1.115	1.240	0.927	1.334	1.504	1.128	1.070
P_3 - 120 kg P_2O_5 ha^{-1}	0.183	0.865	1.025	1.127	1.245	0.937	1.337	1.509	1.132	1.074
Boron Levels										
B_0 - 0 kg B ha^{-1}	0.175	0.859	1.018	1.104	1.236	0.918	1.330	1.501	1.125	1.066
B_1 - 4 kg B ha^{-1}	0.177	0.860	1.020	1.110	1.238	0.923	1.332	1.503	1.127	1.068
Eto (cm)										
I_1 - 0.75 IW/CPE	8.33	13.52	15.80	3.28	7.39	3.76	13.32	12.54	13.46	91.40
I_2 - 1.00 IW/CPE	8.33	13.52	13.67	3.02	10.85	3.66	13.23	10.87	15.41	92.56
I_3 - 1.25 IW/CPE	8.33	13.52	11.37	2.69	13.46	3.60	13.19	12.09	15.56	93.81

Water use efficiency (kg ha-mm^{-1})

Water use efficiency of Lucerne (Table 5) was highest when the crop was irrigated at 0.75 IW/CPE ratio (27.17 and 24.53 kg ha-mm^{-1} in the I and II years, respectively) during both the years of study. Higher water use efficiency of Lucerne in dry regimes (0.75 IW/CPE ratio) is an indicative of its drought resistance character as suggested by Wright *et al.* (1986) [17]. Relatively, Leach and Ratcliff (1979) [9] also opined that development of very deep root system, even beyond 9 m in sub tropics by the pasture of Lucerne may account for its survival during stress period.

Concurrent to higher green fodder yield, phosphorus fertilization @ 80 kg P_2O_5 ha^{-1} (P_2) resulted in maximum water use efficiency during both the years (I year: 27.36 and II year: 25.66 kg ha mm^{-1}). But phosphorus application at highest dose (P_3-120 kg P_2O_5 ha^{-1}) due to higher crop water use has reported water use efficiency closer to P_2 in both the years (I year: 26.69 and II year: 24.94 kg ha-mm^{-1}). Improvement in consumptive use of water and hence water use efficiency in Lucerne due to application of phosphorus was also reported by Hukkeri *et al.* (1976) [5], Dhaliwal *et al.* (1987) [2].

Owing to increased green fodder yield, water use efficiency of the crop also registered higher values due to B_1 with 4 kg B ha^{-1} (25.17 and 23.59 kg ha-mm^{-1} in I and II, respectively) during both the years over B_0. This can be attributed to increased water use of the crop to an extent of 9.39 per cent over B_0.

Table 5: Water use efficiency (kg ha-mm^{-1}) of Lucerne as influenced by irrigation, phosphorus and boron levels during the I and II years of experimentation

Treatments	Water use efficiency (kg ha-mm^{-1})		
	I year	II year	Mean
Irrigation levels			
I_1 - 0.75 IW/CPE	27.17	24.53	25.85
I_2 - 1.00 IW/CPE	25.77	24.28	25.03
I_3 - 1.25 IW/CPE	20.90	20.09	20.49
Phosphorus levels			
P_0- 0 kg P_2O_5 ha^{-1}	19.06	18.08	18.57
P_1 - 40 kg P_2O_5 ha^{-1}	22.60	21.33	21.97
P_2 - 80 kg P_2O_5 ha^{-1}	27.36	25.66	26.51
P_3 - 120 kg P_2O_5 ha^{-1}	26.69	24.94	25.82
Boron levels			
B_0 - 0 kg B ha^{-1}	22.71	21.46	22.09
B_1 - 4 kg B ha^{-1}	25.17	23.59	24.38

Moisture extraction pattern

Soil moisture extraction pattern was maximum from the top 0-15 cm soil depth increment and decreased with each successive soil layer irrespective of irrigation, phosphorus, or boron treatments (Table 6 and 7). The lowest extraction was observed from 45-60 cm soil depth during both years. Irrigations at 1.25 IW/CPE ratio (I_3) resulted in more soil moisture extraction at any soil layer in comparison to I_2 (1.0 IW/CPE ratio) and I_1 (0.75 IW/CPE ratio). Further, the moisture extraction from 0 – 30 cm soil depth increased with an increase in irrigation level (0.75 → 1.25 IWCPE ratio), while the moisture extraction from 30 – 60 cm soil depth increased with a decrease in irrigation level (1.25 → 0.75 IW/CPE ratio). Bulk of soil moisture extraction in different irrigation treatments from 0 – 15 cm soil depth increment varied between 35.5 to 39.0 and 34.8 to 38.1 per cent in I and

II years, respectively. The highest extraction of moisture (I year: 67.8% & II year: 66.8%) was recorded in IW/CPE ratio of 1.25 (I_3) followed by IW/CPE of 1.00 (I year: 65.1% & II year: 64.1%), and was lowest in IW/CPE ratio of 0.75 (I year: 63.4% & II year: 62.7%) from the first half of root zone (0 – 30 cm). On the other side, moisture extraction from 30 – 60 cm soil depth was reverse as compared to 0 – 30 cm with highest extraction at 0.75 IW/CPE ratio (I_1) followed by I_2 and I_3. Obviously, water supply at shorter intervals in I_3 has confined the moisture extraction from upper soil layers due to favorable moisture availability. While irrigations at longer intervals in I_1, had made the crop to depend more on water stored in deeper layers through development of long, finer and more branched roots due to rapid depletion of soil moisture from the upper layers. Similar results were also reported by Patel (1992) [11], Khot *et al*. (1997) [7]. In addition, extraction of moisture from the upper layers (0 – 15 and 15 – 30 cm) was maximum in preceding year (I year) than the succeeding year (II year), while from the lower layers (30 – 45 and 45 – 60 cm) was higher in succeeding year than the preceding year.

High seasonal rainfall in 2in the I year of experimentation has resulted in ready availability of soil moisture from the upper layers for plant extraction due to maintenance of favorable water balance in crop root zone depth at all IW/CPE ratios. Conversely, lowest effective rainfall in II year than the I year has compelled the crop to extend its roots to extract moisture from deeper layers more so in irrigation scheduled at longer intervals (0.75 IW/CPE ratio).

Phosphorus application at graded levels proved beneficial for soil moisture extraction from deeper layers compared to no phosphorus (P_0) treatment. Each incremental dose of phosphorus improved moisture extraction from deeper layers over its lower level during both years, however, the differences were insignificant. Similar finding was reported by Solanki and Patel (1998) [16]. Boron application @ 4 kg ha^{-1} (B_1) also noticed to have no prominent influence on moisture extraction as the differences between B_1 and B_0 (no boron) for moisture extraction pattern at different soil depths were microscopic (Table 6 and 7).

Table 6: Moisture Extraction Pattern (mm) of Lucerne as influenced by irrigation, phosphorus and boron levels during the I and II years of experimentation

Treatments	I year					II year				
	Soil Depth Increment (cm)					Soil Depth Increment (cm)				
	0-15	15-30	30-45	45-60	0-60	0-15	15-30	30-45	45-60	0-60
Irrigation Levels										
I_1 - 0.75 IW/CPE	213.4	167.7	131.6	88.3	601.0	248.0	198.9	159.7	106.2	712.8
I_2 - 1.00 IW/CPE	314.3	244.8	184.6	115.1	858.8	342.7	274.4	208.9	136.7	962.7
I_3 - 1.25 IW/CPE	453.4	334.8	238.3	136.1	1162.6	491.1	370	270.7	157.3	1289.1
Phosphorus levels										
P_0 - 0 kg P_2O_5 ha^{-1}	311.2	240.5	192.7	124.1	868.5	336.5	267.8	222.7	154.1	981.1
P_1 - 40 kg P_2O_5 ha^{-1}	312.0	241.8	193.9	124.7	872.4	338.2	270.2	223.8	153.8	986.0
P_2 - 80 kg P_2O_5 ha^{-1}	315.1	243.7	192.8	124.5	876.1	341.8	271.4	223.9	153.6	990.7
P_3 - 120 kg P_2O_5 ha^{-1}	315.7	243.6	194.3	125.8	879.4	342.2	272.6	224.8	155.2	994.8
Boron Levels										
B_0 - 0 kg B ha^{-1}	310.0	243.8	187.9	131.6	873.3	343.5	273.5	218.2	152.0	987.2
B_1 - 4 kg B ha^{-1}	310.5	244.3	188.2	131.9	874.9	345.2	275.0	217.6	151.4	989.2

Table 7: Moisture Extraction Pattern (%) of Lucerne as influenced by irrigation, phosphorus and boron levels during the I and II years of experimentation

Treatments	I year					II year				
	Soil Depth Increment (cm)					Soil Depth Increment (cm)				
	0-15	15-30	30-45	45-60	0-60	0-15	15-30	30-45	45-60	0-60
Irrigation Levels										
I_1 - 0.75 IW/CPE	35.5	27.9	21.9	14.7	100.0	34.8	27.9	22.4	14.9	100.0
I_2 - 1.00 IW/CPE	36.6	28.5	21.5	13.4	100.0	35.6	28.5	21.7	14.2	100.0
I_3 - 1.25 IW/CPE	39.0	28.8	20.5	11.7	100.0	38.1	28.7	21.0	12.2	100.0
Phosphorus levels										
P_0 - 0 kg P_2O_5 ha^{-1}	35.8	27.7	22.2	14.3	100.0	34.3	27.3	22.7	15.7	100.0
P_1 - 40 kg P_2O_5 ha^{-1}	35.8	27.7	22.2	14.3	100.0	34.3	27.4	22.7	15.6	100.0
P_2 - 80 kg P_2O_5 ha^{-1}	36.0	27.8	22.0	14.2	100.0	34.5	27.4	22.6	15.5	100.0
P_3 - 120 kg P_2O_5 ha^{-1}	35.9	27.7	22.1	14.3	100.0	34.4	27.4	22.6	15.6	100.0
Boron Levels										
B_0 - 0 kg B ha^{-1}	35.5	27.9	21.5	15.1	100.0	34.8	27.7	22.1	15.4	100.0
B_1 - 4 kg B ha^{-1}	35.5	27.9	21.5	15.1	100.0	34.9	27.8	22.0	15.3	100.0

Conclusion

The present study inferred that more frequent irrigations at 1.25 IW/CPE ratio in lucerne has caused more consumption of water during both the years of experimentation. The crop coefficients at different crop growth sub periods corresponded the consumptive use of water with higher values for the irrigations given at 1.25 IW/CPE ratio. consumptive use of water (I year: 116.3 cm & II. The moisture extraction from the surface soil layers (0 – 30 cm soil depth) was also highest with this treatment. Conversely, extraction of soil moisture from sub surface layers (30 – 60 cm soil depth) was highest with 0.75 IW/CPE ratio with highest water use efficiency.

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