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Research article

Effect of NPK rates and irrigation frequencies on the growth and yield performance of *Trifolium alexandrium* L.

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Abstract: The limiting of water resource and traditional farming practices are threatening the sustainability of important minor crops in Pakistan, including berseem, which is a key source of fodder for dairy farms. Each year, 2% reduction of cultivated area, low yield and grower's non-preference (to rotate or replace wheat-cotton pattern) factors are adversely affecting the livestock sector. Consequently, animal rearing business is suffering badly due to lack of fresh forage in the country. Therefore, a three-replicated randomized complete block design (RCBD) field experiment was conducted during rabi season to evaluate berseem crop in term of yield and profit under existing farming practice (85:115:00 NPK kg ha^{-1} + 12 irrigations with 15 days intervals) and optimized treatments (70:100:30 NPK kg ha^{-1}, 55:85:15 NPK kg ha^{-1} + 12, 08, 04 irrigations + 15, 18, 21 days intervals). The net plot size was 12 m^2 with a pH range of 8.1 silty clay loam soil type. In addition, the climate was monitored as well, there was no rainfall observed during the entire crop period. The analysis of statistical data showed a significant ($p < 0.05$) vegetative, reproductive and economic performance of berseem in optimized farming practices compared to traditional practice. Thus, maximum plant height, leaves $plant^{-1}$, branches $plant^{-1}$, plant weight, fodder and seed yield, net profit, and profit on $\$^{-1}$ (81.8 cm, 100.8, 36.0, 19.3 (g), 72.0 t, 829.30 kg ha^{-1}, \$1910.8 ha^{-1}, \$2.03 respectably) were measured from treatment 70:100:30 NPK kg ha^{-1} + 12 irrigations at 15 days intervals, which is recommended to the farmers of synonymic agro-environmental conditions. Furthermore, the treatment 70:100:30 NPK kg ha^{-1} + 8 irrigations was also better with the aspect of satisfactory outcome and 33% less use of water.

Keyword: Egyptian clover; yield; NPK; irrigation; economic analysis

1. Introduction

Berseem (*Trifolium alexandrium* L.) belongs to the family of Papilionaceae and order Leguminosae. It is an important forage legume crop of the Indo-Pak subcontinent. Berseem was first introduced in 1904 in the Mirpurkhas district of Sindh province of Pakistan. After that, it began to be cultivated in the Peshawar region, and then spread widely to the irrigated regions of Punjab within few years. Berseem is now the main source of forage in Pakistan [1], however, the country is facing shortages of fresh forage, each year a reduction of 2% in the fodder cropping area is being observed, together with two forage deficit periods (Nov-Jan and May-June) [2], on other hand, an estimate 4.2% the livestock population is increasing which includes the goats, sheep, cattle, buffaloes, asses, horse and camels. They are in number of 163.0 million heads in the country. The livestock sector of country can be strengthened through a little focus on the cultivation of berseem crop. There are numerous advantages of berseem cultivation, such as high yield, the ability to symbiotically fix nitrogen, add organic matter to the soil [3,4], easily digestible, rich nutritional value, contains 18.3% protein, 2.80% phosphorus, 2.60% calcium and 209 ppm carotene, a rich source of vitamin A [5] and can be grow both in spring and as well as in autumn season [6]. Berseem can give yield about 100 t of green fodder with many cuttings.

Despite several benefits of berseem growing based on research findings from every aspect including farmer’s profit and soil health, the crop cultivation area is very low. Farmer’s general perception is that berseem is low profitable crop as compared to wheat, so, they do not prefer to replace or rotate wheat with berseem, and hence, present fodder production of Sindh, Pakistan (about 13.1%) is insufficient to feed the existing dairy farms and day-to-day, the situation is getting worst, and livestock sector suffering badly. To cope issues, awareness should be given to the farmers that berseem is more profitable crop compare to wheat and in addition of optimized farming practices (fertilizer and irrigation management) can help to achieve high yield and net income, because, famer’s practice become useless due to variation in climatic conditions and soil properties. An appropriate fertilizer and irrigation application is critical to obtain increased productivity of berseem, the supply of essential nutrients (NPK) should be adequate, macro elements help to improve yield performance and enhance its quality. Fresh fodder yield of berseem was increased by an increasing use of nitrogen levels [7]. N directly involves in vegetative growth and photosynthesis process. It is integral part of all proteins. While, P is second essential plant nutrient after nitrogen and second most deficient in Pakistani soils [8]. Insufficient supply causes stunted growth, since it is essential in the process of adenosine triphosphate formation (ATP) and nicotinamide adenine dinucleotide phosphate (NADP) [1]. Several growth and yield parameters, including plant height, diameter, number of leaves and stem biomass were gradually increased using P fertilizers [9,10], along with addition of K with P helps in strong root development and improve water use efficiency, prevents many diseases, heat damages and helps in cycling of nutrients [11]. Many researchers reported that the function of NPK depends on its utilization and it is related to the irrigation scheduling. The big challenge for agricultural scientists is to achieve maximum water productivity [12–14] with fertilizer use efficiency. Low moisture conditions adversely decline the yield of berseem, optimal moist soil is necessary for plant nutrients uptake. Different irrigation scheduling has been suggested in past research studies for the maintenance of soil moisture, but we found that application of irrigation after each cutting significantly increases the yield [15]. In view of the above facts, the study was carried out to investigate the growth and yield performance of berseem under the impact of irrigation levels and different NPK fertilizer rates with the objectives, i. to evaluate the effect of different NPK and irrigation levels on the growth and seed yield of berseem, ii. to find out suitable NPK rate with combination of irrigation frequencies.

2. Materials and methods

A three-replicated randomized complete block design (RCBD) field experiment was conducted during rabi season (2015–2016) at Student's Experimental Farm, Department of Agronomy, Sindh Agriculture University, Tandojam, Pakistan, located at latitude 25.42°N, longitude 68.45°E and 25 m elevation above sea level. The net plot size was 3 × 4 m (12 m^2), and sowing was done with broadcasting on 5 October using seed rate 27 kg ha^{-1}. Source of NPK was Sona urea (46% N bag^{-1}), DAP (46% P_2O_5 & 18% N bag^{-1}) and SOP (50% K_2O bag^{-1}) of a Fauji Fertilizer Company (FFC), it was applied according to local farmer's practices. While, the method of irrigation was surface application. Before the sowing, soil (5 samples at depth of 30 cm) and water properties were tested in the Soil and Water Quality Laboratory (SWQL), the climate was also monitored throughout the crop period with the help of Regional Agromet Center (RAC) (Figure 1), the detail of treatments is given below (Table 1).

Table 1. Fertilizer and irrigation treatments and their combinations.

Fertilizer rates	Irrigation scheduling
F_1 = 85:115:0 NPK kg ha^{-1}	I_1 = 12 irrigations with 15 days interval
F_2 = 70:100:30 NPK kg ha^{-1}	I_2 = 08 irrigations with 18 days interval
F_3 = 55:85:15 NPK kg ha^{-1}	I_3 = 04 irrigations with 21 days interval
Treatments combination	Methods
T1: F_1I_1 = 85:115:00 NPK kg ha^{-1} + 12 irrigations	Farmer's practice
T2: F_2I_1 = 70:100:30 NPK kg ha^{-1} + 12 irrigations	Optimized treatment
T3: F_3I_1 = 55:85:15 NPK kg ha^{-1} + 12 irrigations	-
T4: F_1I_2 = 85:115:00 NPK kg ha^{-1} + 08 irrigations	-
T5: F_2I_2 = 70:100:30 NPK kg ha^{-1} + 08 irrigations	-
T6: F_3I_2 = 55:85:15 NPK kg ha^{-1} + 08 irrigations	-
T7: F_1I_3 = 85:115:00 NPK kg ha^{-1} + 04 irrigations	-
T8: F_2I_3 = 70:100:30 NPK kg ha^{-1} + 04 irrigations	-
T9: F_3I_3 = 55:85:15 NPK kg ha^{-1} + 04 irrigations	-

Data collection: A standard data collection procedure was applied, i.e., fodder yield was obtained from two cuttings (1^{st} cut after 60 days and 2^{nd} cut after 40 days), and then crop left for seed yield, plant height at each cutting recorded based on randomly selected five plants T^{-1} using measuring tape. Leaves $plant^{-1}$, branches $plant^{-1}$ and plant weight (g) were also recorded in each cutting and fodder yield was calculated on the basis of fodder weight of 1 m^2 multiplied with 10000 m^2 for getting fodder yield h^{-1}, while the seed yield was calculated as "Seed yield kg of 1 m^2 × 10000 m^2" and economic analysis was carried out by the formulae "Gross income ha^{-1} − Input cost ha^{-1} = Net profit ha^{-1} ÷ Input cost ha^{-1} = Profit $\$^{-1}$".

Statistical analysis: The collected data were statistically analyzed by two-way analysis of variance (ANOVA) and Fisher's least significant Difference (LSD) test was applied using Statistix 8.1 computer software of Analytical Software PO Box 12185 Tallahassee FL 32317 United states of America (USA) [16], dissimilar ABC letters show a significant variation amongst the treatments at P value less than 0.05. Whole data represented are means ± standard deviations (SD) of three replications for every treatment.

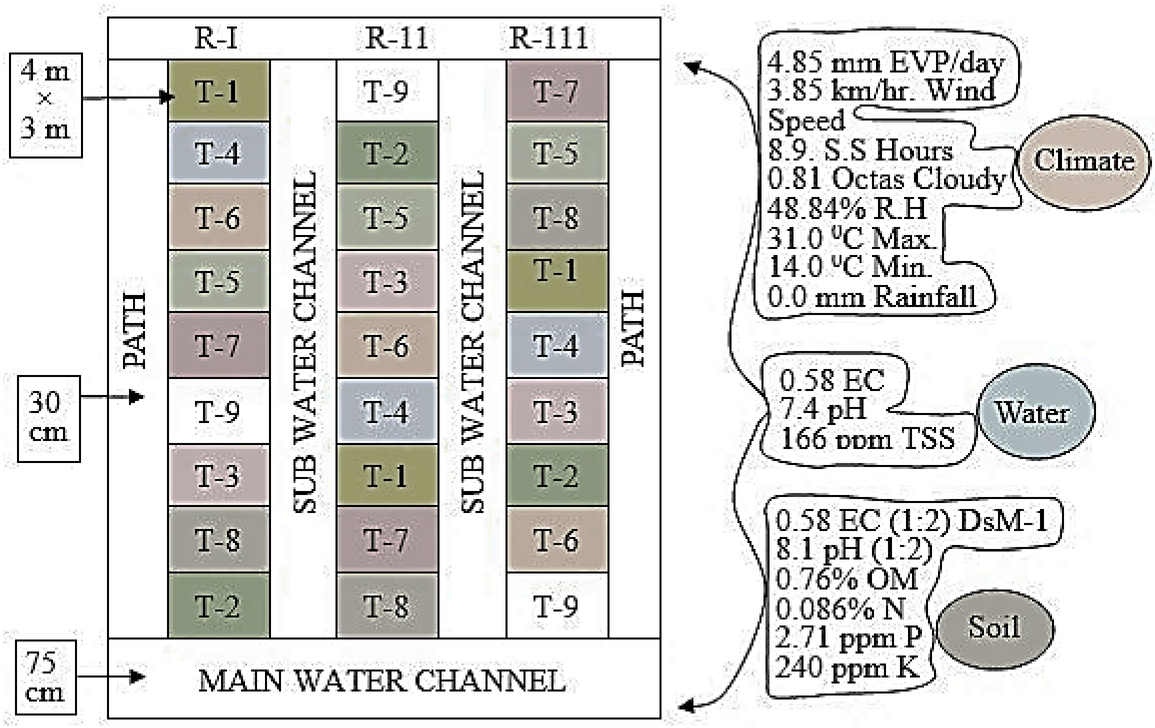

Figure 1. Experimental design, soil, water and climatic conditions (Tandojam).

3. Results and discussion

The balanced application of NPK fertilizer and irrigation inputs are critical during the life cycle of the berseem plant. The major nutrients rapidly increase the growth, and consequently improve the yield [15]. In these lines, exactly, our experimental results showed a maximum plant height, leaves $plant^{-1}$, branches $plant^{-1}$, plant weight (g), fodder and seed yield kg ha^{-1}, i.e., 69.1 cm, 82.1, 28.7, 15.2 g, 55.7 t, 604.7 kg ha^{-1} respectively at optimized ratio 70:100:30 kg NPK ha^{-1}. Whereas, small 57.0 cm plant height, less 68.5 leaves $plant^{-1}$, 22.8 branches $plant^{-1}$, 11.0 (g) plant weight, 40.7 t fodder and 382.8 kg seed yield ha^{-1} were observed at 55:85:15 kg NPK ha^{-1} (Figures 2 and 3). In this study, the rate of fertilizer was not increased, nor it was greatly reduced, but it was optimized with a reduction of 15 kg in recommended NP and that amount of deduction was added in the treatments as 15–30 kg ha^{-1} K (Table 1), since the integrated use of nutrients enhance the yield by correcting the nutrient deficiencies of the plant parts [17,18]. Normally, the plant uses a nutrient with the help of another element by stimulating its growth constituents. Berseem, which is a leguminous crop, does not require more N fertilizer and avail N through root nodulation as atmospheric N fixation process. In addition, PK encourages the fixation of N in berseem by strengthening the root, has great influence [19], high green fodder yield was achieved using 80 kg P ha^{-1}, which could be the result of well nutrient management [20,21].

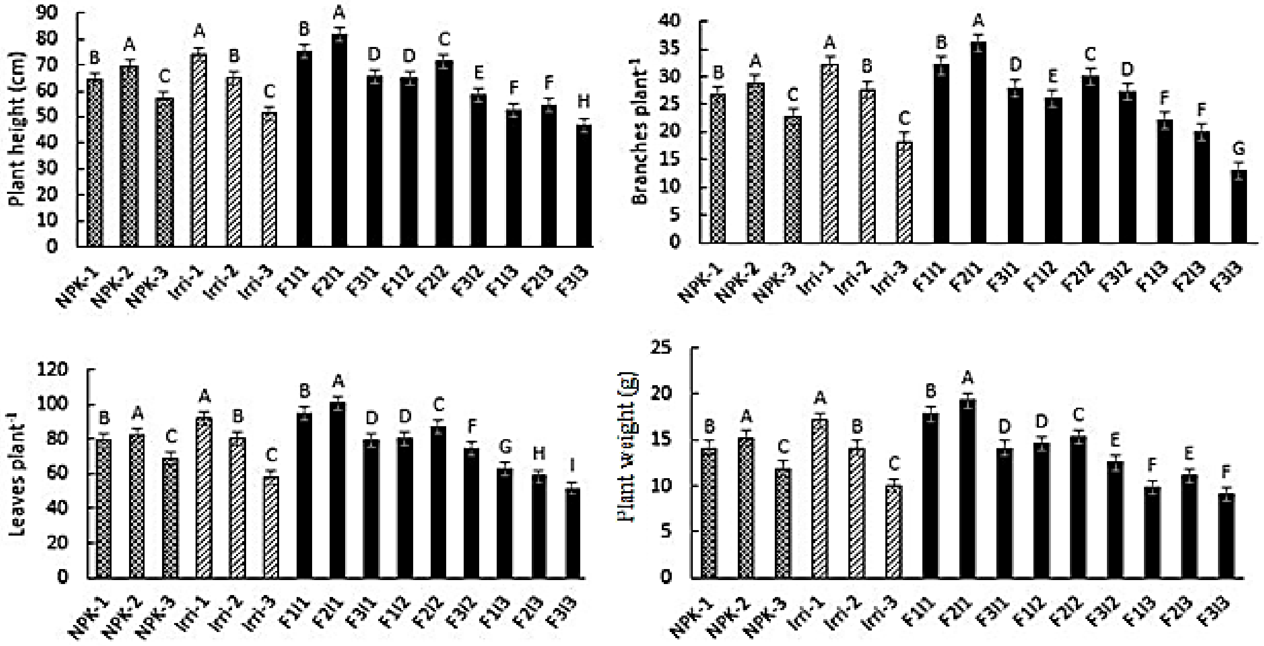

Figure 2. Effect of various NPK rates (kg ha^{-1}) and irrigation frequencies alone or in combination with each other, letters ABC ranking shows a signficance different at $P < 0.05$ for all the growth traits.

In case of irrigation levels, the maximum plant height 74.1 cm, leaves plant^{-1} 91.7, branches plant^{-1} 32.0, plant weight 17.1 g, fodder 61.7 t and seed yield 710.3 kg ha^{-1} were obtained from 12 irrigations applied at 15 days interval. Secondly, 08 irrigations which were applied at the gap of 18 days, produced better height of plant 64.8 cm, leaves plant^{-1} 80.5, branches plant^{-1} 27.7, plant weight 14.0 g, fodder 52.0 t and seed yield 574.7 kg ha^{-1}, and minimum all growth and yield traits were recorded at 04 irrigations. While, the interaction results showed the highest height of plant 81.8 cm, leaves plant^{-1} 100.8, branches plant^{-1} 36.0, plant weight 19.3 g, fodder 72.0 t and seed yield 829.30 kg ha^{-1} in 70:100:30 kg NPK ha^{-1} + 12 irrigations at 15 days interval (T2). The combination of 70:100:30 kg NPK ha^{-1} + 08 irrigation regimes at 18 days gap (T5) also produced good performance with a better plant height 71.1 cm, leaves plant^{-1} 87.0, branches plant^{-1} 30.0, plant weight 15.3 g, fodder yield 58.60 t and seed yield 698.30 kg ha^{-1}. On other hand, all the lowest values noticed for growth and yield parameters at combination of 55:85:15 kg NPK ha^{-1} + 04 irrigations (T9) (Figures 2 and 3). From irrigation point of view, our results are in disagreement with the findings of Daneshni et al. [22], they said that berseem may could not capable to tolerate water scarcity, however, there was also a significant improvement for all growth and yield traits were measured at reduced (08 level) input of irrigation, the plant has the capacity to tolerate water deficiency as well as maximum population density help to provide shade to the root zone soil. Scientifically, plant adjust the temporary drought spell by maintaining the hydration of the tissue [23], and this advantage was noticed in our experiment, extension of the irrigation interval from 15 days to 18 days was beneficial and observed useless when it was extended too much up to 21 days, and we noticed that 18 days gap of irrigation is a critical range, this finding is in line with Ram et al. [24], suggested optimum irrigation scheduling in different aspects, inaccurate irrigation scheduling or shortage of water can reduce 75% leaf area, transpiration and biomass [25], too low water also decreases crop quality [26], 40 seeds head^{-1}, 3.55 g 1000-grain weight, 8530 kg ha^{-1} biological and 508 kg ha^{-1} seed yield were obtained on 10 irrigations, while two irrigations gave 2.99 g 1000-grain weight, 33 seeds head^{-1} and 429 kg ha^{-1} seed yield. The seed yield was severely reduced about 47% when the irrigation was decreased from ten to four irrigations; this could be, because of flowers and head abscission under moisture stress [27], since the yield traits of berseem clover are correlated with soil moisture conditions [28]. These results are in agreements with our outcomes, we obtained maximum yields by increasing of irrigation regimes up to 12, but it was noticed under optimized NPK rate, rather than farmer's practices. Current results are clearly indicating that irrigation scheduling along with NPK management for berseem crop is most important to achieve desirable yield at Tandojam (Pakistan) (Figure 4) agroecological conditions.

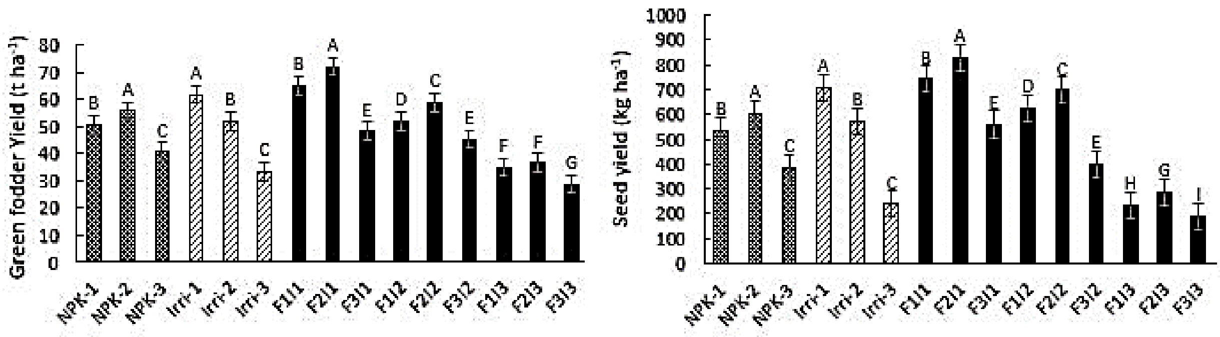

Figure 3. Effect of various NPK rates (kg ha^{-1}) and irrigation frequencies alone or in combination with each other, letters ABC ranking shows a signficance different at $P < 0.05$ for yield perameters.

Economically, our results also proved that berseem is a profitable crop. It provided premium net return, hence could be said as "Silvers Crop", study results are clear evident, high net profit $1910.8 ha^{-1} and $2.03 profit on \$$^{-1}$ (invested) were obtained from 70:100:30 kg NPK ha^{-1} + 12 irrigations. While, combination of 70:100:30 kg NPK ha^{-1} + 08 irrigations (T2) produced $1358.3 net income and $1.4 profit on \$$^{-1}$ (Table 2). From the finding of current research, we can say that berseem should be cultivated as a cash crop by replacing wheat, these results are agreeing with Khan et al. [29], they compared berseem with wheat for profitability and said that berseem is more profitable than wheat crop which showed increased input-output ratio and net revenue about 32.7% greater in comparison with wheat. Wheat resulted $1061.80 gross and $398.19 average net income ha^{-1}, whereas, berseem showed $1079.98 average gross and $528.33 as net revenue ha^{-1}. High profit from the berseem crop is due to high herbage yield and its demand. In Pakistan the deficit between demand and production is providing high rates of berseem to the farmers. If the farmers of Tandojam area replace cropping system with berseem crop, then they can earn high income ha^{-1} as compare to traditional cultivation of wheat.

Table 2. Economic Analysis of berseem crop.

Treatments	Productivity Fodder yield (t)	Seed Yield (kg)	Input Cost ($)	Net Profit ($)	Profit on $$^{-1}$
$T_1 = F_1I_1$	64.80	741.60	933.10	1625.8	1.740
$T_2 = F_2I_1$	72.00	829.30	939.90	1910.8	2.032
$T_3 = F_3I_1$	48.30	560.00	905.80	1013.9	1.119
$T_4 = F_1I_2$	52.00	627.60	933.10	1166.0	1.249
$T_5 = F_2I_2$	58.60	698.30	939.90	1358.3	1.445
$T_6 = F_3I_2$	45.33	398.30	905.80	694.80	0.767
$T_7 = F_1I_3$	35.00	235.00	933.10	189.12	0.202
$T_8 = F_2I_3$	36.60	286.70	939.90	298.00	0.317
$T_9 = F_3I_3$	28.60	190.00	905.80	96.000	0.105

Figure 4. Crop at maturity stage (An experimental trial view).

4. Conclusion

Based on the indication of results, the fertilizer rate 70:100:30 kg NPK ha^{-1} found optimum dose for better growth, yield and net return of berseem. In case of irrigation regimes, 12 irrigation produced significant green fodder and seed yield. Thus, optimized 70:100:30 kg NPK ha^{-1} + 12 irrigations concluded as suitable application compared to farmer's traditional practice, and next, the treatment 70:100:30 kg NPK ha^{-1} + 08 irrigations is suggested for the water shortage areas of Sindh province of Pakistan.

Economically, our results also proved that berseem is a profitable crop. It provided high net return, hence berseem could be said as "Silvers Crop'' and can be cultivated as a cash crop by replacing wheat.

Conflict of interest

The authors declare no conflict of interest.

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