Egypt. J. Agron. **Vol. 44**, No. 1, pp. 1-9 (2022)

Egyptian Journal of Agronomy

http://agro.journals.ekb.eg/

Enhancing Seed and Fodder Yield Potential of Berseem (*Trifolium alexandrinum* L.) with Combined Application Phosphorous and Potassium under Irrigated Conditions of Bahawalpur, Pakistan

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PROPER nutrient management in crop production not only improves and stabilizes the yield, but also improve the environmental health. The productivity of berseem affected by nutrient imbalances and Poor soil fertility. An experiment was conducted to evaluate the effect of various levels of phosphorus and potassium fertilizer on the forage and seed yield of berseem. The experiment was laidout in 3 X 4 factorial arrangement in a Randomized Complete Block Design (RCBD) with three replications. The P levels used were 40, 60 and 80kg ha^{-1} and K levels were 0, 15, 30 and 45kg ha^{-1}. The statistical analysis data showed a significant (P< 0.05) effect on growth parameters like Crop Growth Rate (CGR), Lead Area Index (LAI) and Leaf Area Duration (LAD) of berseem in optimized fertilizer practices compared to traditional farming practice. Results recorded revealed that highest crop growth rate (5.20g m^{-2} day^{-1}), Leaf Area Index (2.17) and Leaf Area Duration (125.10 days) were estimated in T8 where PK were applied @ 60:30kg ha^{-1} compared to all other fertilizer doses. Similar results were recorded in yield and yield attributes. The results of the study showed that maximum plant height (76cm), No. of seed per capsule (46), 1000 seed weight (1.77g), fodder yield (82tons ha^{-1}) and seed yield (617kg ha^{-1}) was obtained in T_8. The combination of fertilizer gave maximum potential seed yield and other parameters rather than fertilizers alone.

Keywords: Bahawalpur, Berseem, Fodder yield, Phosphorous, Potassium, Seed yield.

Introduction

Worldwide Sustainable crop production focused due to reduction in production resources and increased population in current and imminent farming systems. Fodder crops played a dynamic role in agriculture for increasing demand of fodder as it required for livestock to fulfill the increasing milk demand for human beings (Roy et al., 2015). The Berseem (*Trifolium alexandrinum* L.) is one of the most important forage legumes in Pakistan. Berseem was introduced in India in 1903 domesticated in Egypt and later introduced in other parts of world. It was first introduced in Sindh and Peshawar. Now, it is a major fodder crop in irrigated areas of the country (Beena et al., 2011a). Berseem is used in recent decades and is so popular for farmers because of its fast growth, high number of harvests and fresh forage production with good quality and quantity. The results of research showed that rate of berseem production depends on sowing date, climate condition, soil fertility, shrub height, the number of harvests and variety (Seyede et. al., 2015). Berseem is known as king of fodder crops due to its palatability and high forage nutritive value. It has become very popular rabi fodder in irrigated areas of the country (Roy et al., 2009). As the cheapest source, it provides

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Received 05/10/2021; Accepted 01/03/2022
DOI : 10.21608/agro.2022.99606.1282

feed before the occurrence of winter. The optimum temperature for successful growth is 18-25 °C but if temperature falls to 6-8 °C crop severely affected (Nand et al., 2018). The growth and development of plant depends on nutrient availability and increase in yield of crop linked with proper nutrient management in crop production systems. The forage productivity enhanced by applying fertilizers and chemical fertilizers have fast effect and only small amounts required for crop growth as they have high nutrient content (Nand et al., 2018). Phosphorus as a macronutrient after nitrogen required for root growth and helps in absorption of nutrients. Berseem, being a leguminous crop, requires sufficient quantity of phosphorus in free form for better nodulation. Due to dual purposes in legumes, i.e. growth of plant and its associated biological nitrogen fixing bacteria it required more potassium and phosphorous compared to cereals (Ayub et al., 2012). Phosphorous is required for energy transfer system and many enzymatic reactions in plant. The combination of Farm Yard Manure (FYM) with chemical fertilizer like rock phosphate improved crop yield (Shafi et al., 2012). Application of phosphorus significantly increased the fodder yield, leaf area per plant, plant height, number of leaves per plant and stem diameter (Munir et al., 2004). Potassium played important role in improving protein synthesis, activity of enzymes, translocation of assimilates and carbohydrates synthesis. The fodder and seed production is highly influenced by the application of Boron, molybdenum and potassium. Out of these nutrients, potassium mainly effects translocation of nutrients, water uptake and protect plant from abiotic stresses through thermos-tolerance, which help in regular functioning of plant for longtime (Rab & Ihsan-ul Haq, 2012). Potassium and phosphorous fertilization also significantly affected the dry forage yield (Beena et al., 2011b). Due to competition for resources like light, water and nutrients plant growth may be limited (Friday & Fownes, 2000). Among the various factors, Phosphorus and Potassium application is important which directly contributes to the quality and quantity of fodder and seed production.

Materials and Methods

Experimental site and field preparation

The experiment was carried out at Research Area of Agricultural Research Station, Bahawalpur during 2019-2020 to investigate the effects of P and K on the growth, yield and yield attributes of berseem (berseem agaiti) crop. The experiment was laidout in 3 X 4 factorial arrangement in a Randomized Complete Block Design (RCBD) with three replications. The P levels used were 40,60 and 80kg ha^{-1} and K levels were 0, 15, 30 and 45kg ha^{-1}. Pre-sowing irrigation was carried out and soil was prepared to obtain fine tilth. Crop stubbles and weeds were removed with cultivator before sowing with planking for equal distribution of irrigation water.

Morpho-physiological traits

Growth measurements were started at 40 Days After Sowing (DAS) with fifteen days interval and growth parameters i.e. crop growth rate (CGR), leaf area index (LAI) and leaf area duration (LAD) were measured. Five plants from each plot were taken. Fresh weight was recorded using digital weight balance. Leaves taken from three biological replicates were used to obtain measurements of leaf area and Leaf area index. These plants were over dried and then dry weight was recorded using digital weight balance. Formulas were used as given below:

Leaf area index

Leaf area index was calculated as the ratio of leaf area to land area (Chen & Black, 1992):

LAI= Leaf area/ Land area

Leaf area duration

Leaf area duration was calculated according to the method of Hunt (1978):

LAD1= (LAI1+ LAI2)/2 * (T2-T1)

whereas LAI1 and LAI2 are the Leaf area indices at times, T1 and T2 respectively and consecutive LADs were calculated as:

LAD2= (LAI2+LAI3)/2 * (T2-T1) +LAD1

Crop growth rate (g m^{-2} day^{-1})

CGR= W2-W1/T2-T1

whereas W1= Weight at 1st harvest and W2= Weight at 2nd harvest, T2= Time of 2nd harvest and T1= Time of 1st harvest.

Soil analysis

Soil samples were collected from experimental site at the depth of 0-30 cm before sowing and after harvesting according to experimental plan. Soil samples were sent to soil and water testing laboratory for analysis. Soil Available Phosphorous (Watanabe & Olsen, 1965), Exchangeable Potassium (Rhoades, 1982) while soil pH and Ece was measured by the methods described by Mclean

(1982) and Richards (1954) respectively. Results communicated by SAWTL were shown in Table 1, Fig 4 and Fig 5.

Economic analysis

Economic analysis of variable rates of fertilizer application was estimated and net profit calculated for comparing different rates of fertilizers (Table 4).

Results and Discussion

Effect of PK application on the growth parameters of Berseem

The growth and yield improved rapidly due to application of NPK fertilizer at critical growth stages of berseem (El-Bably, 2002). Growth refers to the irreversible changes in the size of a cell, organ or whole plant. It involves both the cell division and enlargement. Growth parameters can confer in terms of increase in cell numbers, fresh weight, dry weight, plant height, leaf area index, crop growth rate and leaf area duration etc. The following growth parameters of the experiment were recorded.

Leaf area index

The response of berseem crop to phosphorous and potassium showed significant ($P<0.05$) effect for leaf area index (Fig. 1). Leaf area index is one of the main parameters in measuring crop growth. The results showed that berseem leaves reached their maximum expansion at 115 days from sowing, then it declined sharply at 120 days from sowing due to maximum leaf expansion and indication towards maturity. The results interpreted in Fig. 1 revealed that significant effects were observed due to Phosphorous and Potassium at all growth stages for leaf area index at maximum (2.17) in T8 and gradually decreased as PK application rate increased. In addition, Leaf area index showed a steady increase up to a specific growth period and decreases after 120 DAS that may be due to maturity of lower leaves (Fig. 1). The increasing dose of phosphorus fertilizer resulted in the growth of meristematic tissue and assimilation of nutrients due to higher leaf area index. Phosphorus indirectly may contribute for leaf expansion, leaves appearance, canopy size and leaf area index. Results indicated that maximum leaf area index (2.17) was recorded in T8 (60:30kg ha^{-1}) and increased up to specific level of phosphorous and potassium but started to decline at higher rates of PK application (Table 2). Hence, the rate of increase was fast at middle growing periods trending to decrease after 120 DAS but increased with increasing PK doses. Contrarily, the leaf area index did not increased with phosphorous application in potato crop (Gelaye et al., 2021). Leaf area index is a dynamic factor that also depends on existing site conditions, genetic variations, agronomic practices and developmental stages. The fertilizer use efficiency increased due to increased uptake of nutrients from the soil resulting in rapid leaf area expansion, which leads to rapid canopy development (Richards et al., 2002). Growth performance of Berseem revealed integrated use of fertilizers in sunflower significantly increased the plant height, leaf area index, oil yield and biomass in sunflower compared to sole chemical or organic application (Shoghi et al., 2013).

TABLE 1. Selected physico-chemical characteristics of soil (0-30cm depth) before sowing

Treatments (P:K) (kg ha^{-1})	Before sowing			
	pH	Ece (dSm^{-1})	Available P (kg ha^{-1})	Exchangeable K (kg ha^{-1})
T1(40:0)	8.0	1.02	11	140
T2(60:0)	7.8	0.96	13	138
T3(80:0)	7.9	0.93	12	141
T4 (40:15)	7.8	0.95	11	145
T5(60:15)	7.9	1.04	14	145
T6(80:15)	8.2	1.05	13	154
T7(40:30)	8.0	1.04	14	144
T8(60:30)	7.9	1.11	15	156
T9(80:30)	8.1	1.04	13	167
T10(40:45)	8.3	1.06	12	165
T11(60:45)	7.9	1.03	12	172
T12(80:45)	8.2	1.09	14	179

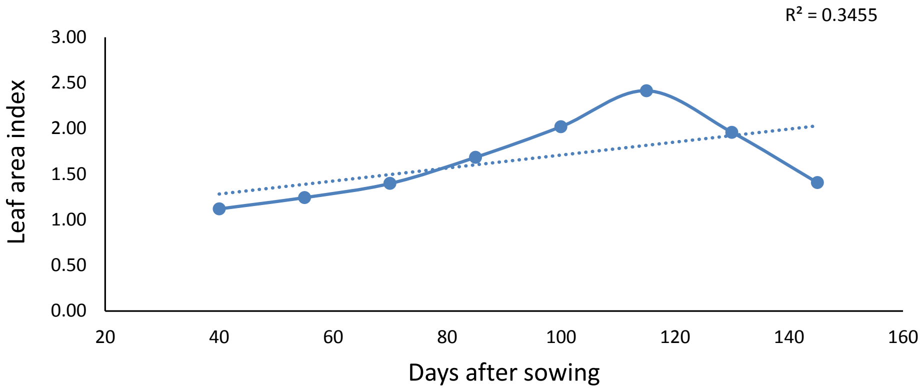

Fig. 1. Leaf area index during the crop growing period as affected by phosphourous and potassium

TABLE 2. Effect of phosphorous and potassium on the growth parameters of Berseem

Treatments (P:K) (kg ha^{-1})	LAI	CGR (g m^{-2} day^{-1})	LAD
T1(40:0)	1.12 h	4.64 l	62.23 h
T2(60:0)	1.33 g	4.75 k	74.83 g
T3(80:0)	1.43 ef	4.80 j	80.95 ef
T4 (40:15)	1.47 e	5.00 f	83.34 e
T5(60:15)	1.57 d	5.05 e	89.46 d
T6(80:15)	1.98 c	5.10 d	113.58 c
T7(40:30)	2.11 b	5.16 b	121.50 b
T8(60:30)	2.17 a	5.20 a	125.10 a
T9(80:30)	2.06 b	5.13 c	118.62 b
T10(40:45)	1.58 d	4.91 h	89.95 d
T11(60:45)	1.61 d	4.94 g	91.39 d
T12(80:45)	1.42 f	4.84 i	79.92 f
LSD	0.06	0.02	3.31

Crop growth rate (g m^{-2} day^{-1})

The results of the study showed that phosphorous and potassium showed significant ($P<0.05$) effect for crop growth rate (g m^{-2} day^{-1}) (Fig. 2). The rate of crop growth measured by the parameter CGR that showed the day to day development in growth. The results showed that maximum crop growth rate (9.14g m^{-2} day^{-1}) was achieved at 115 DAS and decreased after 115 DAS that showed the crop shifted toward maturity (Fig. 2). Moreover, maximum crop growth rate (5.20g m^{-2} day^{-1}) was obtained in T_8 where PK was applied @ 60:30kg ha^{-1} followed by T_7 (5.16g m^{-2} day^{-1}) where PK applied @ 40:30kg ha^{-1} (Table 2) while minimum crop growth rate (4.64g m^{-2} day^{-1}) was recorded in T_1 where only Phosphorous applied that may be due to enhanced phosphorous and potassium uptake and synergistic effect which increase the CGR at vegetative stage and delayed physiological maturity. Consistently, due to the fixation of phosphorous in the soil, the efficiency of phosphorous fertilizer was low alone while high in combination with potassium fertilizer. In addition, Habibzadeh et al. (2006) reported that photosynthetic area directly affected the crop growth rate. Increased rate of fertilizer PK significantly increased crop growth rate (CGR) at early growth period and reduced the net assimilation rate (NAR) and CGR during later crop growth stage. Leaf area index and NAR controlled by crop growth at vegetative stage. Higher CGR means more leaf area index. The better habitat for the activity of biological nitrogen fixing bacteria is the result of higher rates of PK application that resulted in higher CGR rate and more yield (Vishuddha et al., 2018). The development of healthy roots due to PK application exploit the nutrients from soil and resulted in more CGR (Ayub et al., 2012).

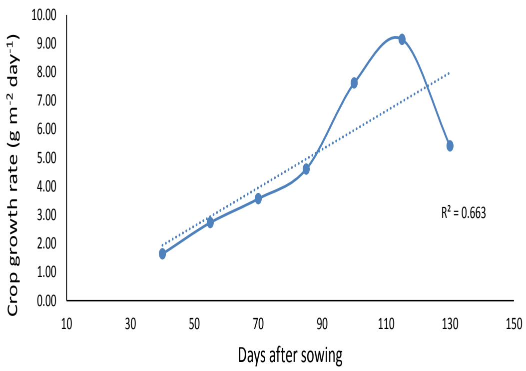

Fig. 2. Crop growth rate during the crop growing period as affected by phosphourous and potassium

Leaf area duration

The analysis of variance showed that phosphorous and potassium significantly affected the leaf area duration (Table 2). The leaf area duration showed the viability of crop and greenness in berseem crop. The results of the study showed that maximum leaf area duration (179.59) at 130 DAS (Fig. 3). However considering the PK doses maximum LAD (125.10) was achieved in T_8 where PK applied @ 60:30kg ha^{-1}) followed by T_7 (121.50) that may be due to enhanced phosphorus and potassium availability to berseem crop which increased the leaf area duration while minimum leaf area duration (62.23) was recorded in control (Table 2). Moreover, higher crop growth rates resulted in more leaf area duration and high leaf expansion lineated to more assimilates to leaves and stems which resulted in more yield. These results are in line with Bultynck et al. (2004) who reported that phosphorus applications shortened date of physiological maturity. The species with more rapidly elongating leaf showed a faster increase with leaf position in leaf expansion rate, leaf width and leaf area, higher relative leaf area expansion rates, and more biomass allocation to leaf sheaths and less to roots.

Effect of PK application on the yield and yield attributes of Berseem

The macro elements help to increased productivity of berseem and its quality due to adequate application of NPK and irrigation management (Leghari et al., 2018). It is clear from the data presented in Table 3 that combination of PK has a promotive effect on the seed yield and yield attributes like plant height, no. of seeds per capsule and 1000 seed weight of berseem. The PK application at the rate of (60:30) gave the highest value for plant height (76cm), no. of seeds per capsule (46), 1000 seed weight (1.77g), fodder yield (83tons ha^{-1}) and seed yield (617kg ha^{-1}) and further increase in the fertilizer rate had negative effect on the yield and yield attributes of berseem. The data showed that minimum values for plant height (47cm), no. of seeds per capsule (33), 1000 seed weight (1.18g), fodder yield (59tons ha^{-1}) and seed yield (260kg ha^{-1}) were recorded in T_1 where PK were applied at the of 40:0 Kg ha^{-1}. It is clear from the data shown in Table 3 that application of P alone did not give higher plant height, no. of seeds per capsule, 1000 seed weight, fodder yield and seed yield. These results are comparable with Anurag et al. (2002) and Reager et al. (2003) for the plant height. The increase in the fresh weight of leaf and plant height might be due to available nitrogen utilization and more assimilation during the growth period (Valiki et al., 2015). In addition, Roy & Jana (2016) reported that PK boosts the fixation of Nitrogen in berseem, showed strengthening of root and increase in fodder yield with the application of P at the rate of 80kg P ha^{-1} that may be due to nutrient management in berseem crop. The soybean yield, growth, photosynthesis and nitrogen fixation influenced due to application of phosphorous fertilizer (Naeem et al., 2018). The application of PK at the rate of 60:30kg ha^{-1} gave highest seed and fodder yield that may be due to more plant height, no. of seeds per capsule and 1000 seed weight in berseem, also reported by Frossard et al. (2000) that the integrated use of nutrients increases the yield by improving nutrients deficiencies in plants. Also reported by Coksun et al. (2017) that potassium played a vital role in the root transport system for improving enzymatic reactions and strengthened the source-sink relationship, which resulted in higher seed yield. In addition, phosphorous and potassium assures the nitrogen fixation in berseem by solidification of root which influenced the green fodder yield (Ali et al., 2014) and that may be due to well nutrient management (Roy & Jana, 2016). Contrary to this, Ayub et al. (2012) stated that increasing phosphorus and potassium rates had no associated effect on plant height at all the stages of plant growth. Normally, nitrogen fixation in root nodules occurs in berseem crop and does not require nitrogen fertilizer that may be due to optimized use of NP fertilizer that enhanced the yield of berseem (Leghari et al., 2018).

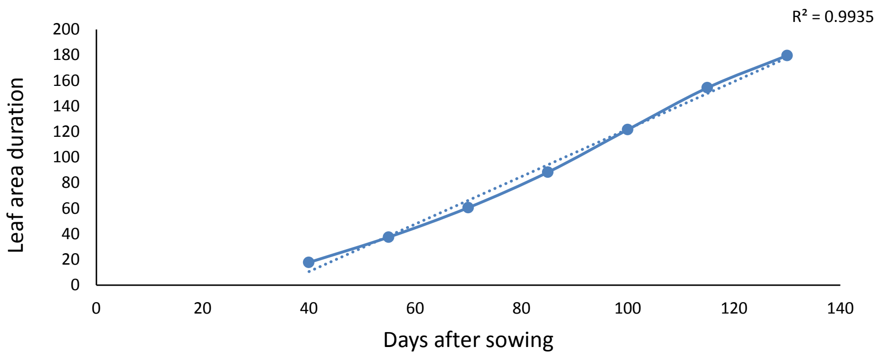

Fig. 3. Leaf area duration during the crop growing period as affected by phosphourous and potassium

TABLE 3. Effect of Phosphorous and potassium on the yield and yield attributes of Berseem

Treatments (P:K) (kg ha^{-1})	Plant height (cm)	No. of seeds per capsule	1000 seed weight (g)	Fodder yield (ton ha^{-1})	Seed yield (kg ha^{-1})
T1(40:0)	47 h	33 f	1.18 d	58.70 e	260 g
T2(60:0)	50 gh	35 ef	1.25 d	66.48 d	306 fg
T3(80:0)	52 fgh	36 def	1.38 cd	68.89 cd	321 efg
T4 (40:15)	62 cd	39 bcd	1.68 ab	75.19 bc	363 def
T5(60:15)	63 cd	42 abc	1.71 a	76.48 ab	381 de
T6(80:15)	65 bcd	43 ab	1.73 a	75.56 abc	419 cd
T7(40:30)	69 b	45 a	1.75 a	78.89 ab	520 b
T8(60:30)	76 a	46 a	1.77 a	82.59 a	617 a
T9(80:30)	68 bc	44 a	1.74 a	75.56 abc	462 bc
T10(40:45)	56 ef	37 def	1.57 abc	73.80 bc	340 ef
T11(60:45)	61 de	38 cde	1.63 ab	74.17 bc	344 ef
T12(80:45)	54 fg	37 def	1.49 bc	73.15 bcd	324 efg
LSD	5.68	4.039	0.21	5.80	64.29

*Any two means not sharing the same letter differ significantly at 5% probability.

Effect of PK application on the phosphorous and potassium levels at the site after harvesting of berseem crop

The results of the soil analysis at the study site indicated that potassium application increase the level of phosphorous in soil (Fig. 4). On the other hand phosphorous application @ 60kg ha^{-1} rises the level of potassium (171kg ha^{-1}) but decreased with the increase in phosphorous application rate. The concentration of exchangeable potassium improved compared to control by the application of phosphorous application (Fig. 5). The application of phosphorous above the rate of 60kg ha^{-1} considerably reduced the level of potassium in soil. However, the highest exchangeable potassium (171kg ha^{-1}) was recorded from the application of phosphorous @ 60kg ha^{-1} while lowest concentration of potassium (164kg ha^{-1}) was obtained in control (Fig. 5).

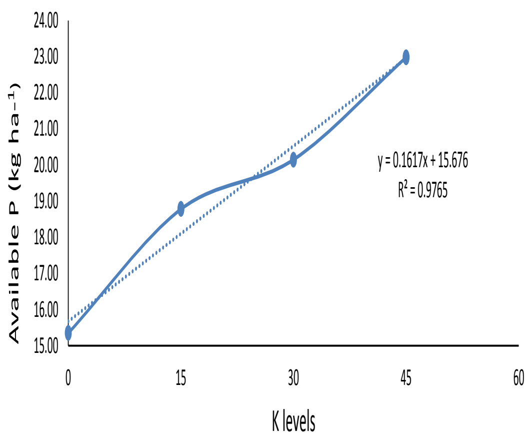

Fig. 4. Available phosphorous as influenced by potassium application after harvesting of berseem crop

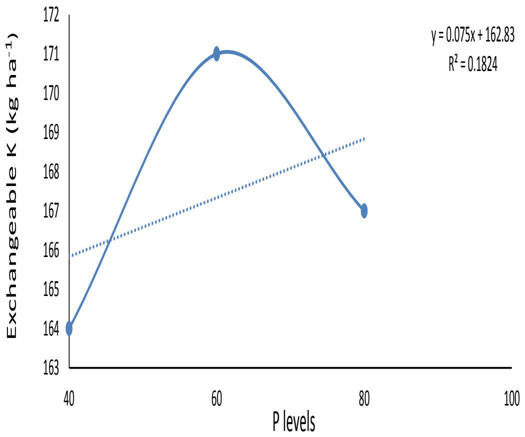

Fig. 5. Exchangeable potassium as influenced by phosphorous application after harvesting of berseem crop

These results are in line with Gelaye et. al. (2021) who reported that phosphorus fertilizer (34.5kg ha^{-1}) application rises the concentration of potassium upto a certain level (0.26cmol) in the soil but the concentration declines when the rate of phosphorus was maximized whereas potassium fertilizer application increase the level of phosphorous in the soil. Also Reported by Khan et. al. (2019) who stated that disproportionate use of fertilizers, i.e. nitrogen and phosphorous may intensify the potassium deficiency symptoms in different crops and continuous use of nitrogen and phosphorus accelerate the depletion of native potassium soil reserves which is responsible for potassium deficiency and low crop yields. The highest (22.98kg ha^{-1}) and lowest (15.35kg ha^{-1}) available phosphorous was acquired from the application of 45 kg ha^{-1} and 0 kg ha^{-1} potassium respectively. In accordance with the results, the soil fertility has been made to optimum level of nutrients use in closely competitions of nutrients in the soil for obtaining maximum yield.

Economic analysis

From the findings of study conducted, we can conclude that maximum net benefit (Rs. 247967) was obtained in T_8 where PK were applied at the rate of 60:30kg ha^{-1} due to more seed and fodder yield in return of appropriate PK fertilizer application while minimum Net Income (157056) was calculated in T_1 where in P was applied alone. We can say that berseem cultivated as a cash crop should be treated by appropriate PK fertilizer at the rate of 60:30kg ha^{-1} as it gives 57.88% more net revenue compared to all other fertilizer combinations (Table 4). These results are in line with Khan et al. (2012), they compared berseem with wheat and concluded that berseem gave 32.7% more profit than wheat.

TABLE 4. Economic analysis of different rates of PK fertilizer application to Berseem crop

Treatments / (P:K) (kg ha^{-1})	Seed yield (kg ha^{-1})	Fodder yield (ton ha^{-1})	Gross Income Rs.			Total cost of fertilizer	Net income
			Seed	Fodder	Total		
T1(40:0)	260	59	39056	118000	157056	0	157056
T2(60:0)	306	66	45889	130000	175889	3000	172889
T3(80:0)	321	69	48556	138000	186556	5950	180606
T4 (40:15)	363	75	51056	140000	191056	9333	181723
T5(60:15)	381	76	49278	134000	183278	1200	182078
T6(80:15)	419	76	62778	152000	214778	4200	210578
T7(40:30)	520	79	69278	158000	227278	7150	220128
T8(60:30)	617	83	92500	166000	258500	10533	247967
T9(80:30)	462	76	51611	144000	195611	2400	193211
T10(40:45)	340	74	56333	148000	204333	5400	198933
T11(60:45)	344	74	60389	152000	212389	8350	204039
T12(80:45	324	73	77944	152000	229944	11733	218211

Note: All the calculations done based on current market rate of fertilizer, fodder and seed of berseem that may vary with time to time.

Conclusion

The study revealed that optimum use of PK fertilizer resulted in higher crop growth rate of berseem and seed yield, also advantageous for improvement in fodder quality. The results suggested that the PK fertilizer @ 60:30kg ha^{-1} found optimal rate of application for better growth and yield of berseem crop. Economically, our results also proved that application of PK @ 60: 30kg ha^{-1} PK in berseem is a profitable for net return to the farmers.

Acknowledgement: We are thankful to Dr Lal Hussain Akhtar for providing scientific and technical guidance and to our team members for conducting and executing research work.

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