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Productivity of berseem (*trifolium alexandrinuum*) sown alone and in combination with other fodder crops

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Abstract

In Pakistan, berseem (*Trifolium alexandrinum* L.) is grown either alone or together with canola or sarson. Berseem has high protein content, but it is considered to have low dry matter content mostly in the first cut. Field experiments were conducted at Agronomy Section (Forage Production), Ayub Agricultural Research Institute, Faisalabad, Pakistan during 2019-20 and 2020-21. The major objective of the experiment was to find out the best combination of fodder with berseem in order to get maximum green fodder yield with high protein content. Berseem was sown alone and in combination with oats, sarson, barley, haalun and ryegrass with different proportions by keeping "Super Berseem" as a base variety following RCBD with four replications. The crops were sown on 9th October 2019 and 12th October 2020. First cut was taken on 26th December during both years while subsequent cuts were taken on 15th February, 22nd March, 26th April during the year 2020, and 17th February, 25th March, 28th April during the year 2021. Results revealed maximum green fodder yield of 136.58 t ha^{-1} from plots where berseem 75% + oats 25% was sown, followed by berseem 75% + barley 25% was mixed (129.83 t ha^{-1}). Maximum protein content (19.23%) was obtained where berseem alone was sown, followed by the treatment where berseem and ryegrass (18.40 %) were mixed. Mixed cropping of berseem 75 % + barley 25% produced the maximum crude fiber. It is recommended for farmers that berseem 75% + oats/barley 25% combination is more productive in quantitative terms, while qualitatively, berseem alone is the best option, particularly for mulching animals.

Keywords: Berseem, Fiber content, Green fodder yield, Mixed cropping, Protein content

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Introduction

Berseem is a valuable forage legume crop of winter season in Pakistan. It covers an area of 78% among other winter fodders. Area under fodder crops in Pakistan is 2.31 million hectares with production of 51.92 million tons (Ali, 2019). Some varieties of berseem have the potential to enhance fodder yield two to three times when compared with some present varieties (Al-Khateeb et al., 2001). It is a popular fodder for milch animals, which provides economical and superior nutrition for longer periods and helps in increasing milk production. Furthermore, it is a legume fodder which ameliorates soil by adding nitrogen to soil.

Intercropping or mixed cropping is an important tool for the development of sustainable food production in cropping systems with limited external inputs (Maitra et al., 2021). Mixing berseem with winter forage grasses provides a high amount of balanced nutritious forage to smallholder livestock producers to support the forage-based feeding systems while mixture produced higher yield as compared to legume or grass alone. (Salama, 2020). Traditionally, berseem is either sown alone or in mixture with canola or sarson crop to get higher green fodder yield from the first cut because the first cut of berseem usually gives low yield due to less tillering as compared to later cuts. The green fodder yield of berseem sown mixed with canola enhances but with little effect on quality. Intercropping of berseem (*Trifolium alexandrinum* L.) with ryegrass or barley may improve forage quality and yield. Mixed cropping increases dry matter yield, which is primarily due to the benefit of the companion grasses from nitrogen fixed by the legume (Al-Khateeb et al., 2001). Many farmers have little information about the roles of seed quality and rhizobium inoculation. Same is the case with modern production technology and nutritional value in improving livestock production, instead relying on traditional methods. Government or private sector is providing no subsidy to inputs, as inputs are very expensive (Tufail et al., 2017).

Berseem has high protein content, but it is considered to have low dry matter content mostly in the first cut. Thus, mixed cropping of berseem with forage grasses is a low input

technology that has many positive effects on forage productivity and nutritive value (El-Karamany et al., 2014). Furthermore, along with the advantage of getting more yield through mixed cropping of fodder, legumes supply nitrogen to companion grasses which reduces the need of nitrogenous fertilizers. Grasses in legume mixtures also have a higher protein content. These mixtures are also more palatable to animals (Rusdy, 2021).

Obour et al. (2021) narrated that using cover crops for forage provides an opportunity to control weeds, improve soil health, and enhance profits of crop production. On the contrary, legume sown alone is likely to produce less biomass and have limited potential of weed suppression. Site-specific or regional research is required to determine the best mixtures and species that could balance weed suppression, grazing and soil health outcomes. The selection of successful mixtures should be from those forage crops that have compatible maturity & harvesting schemes, complement each other in growth distribution & ecological niche and do not severely compete with each other for their growth and life requirements (Maitra et al., 2021). Similarly, Salama (2015) revealed that mixture of berseem and annual ryegrass sown with different ratios improved forage yield and dry matter content significantly. Pure berseem stands had more crude protein content, while pure ryegrass had more fiber fraction. However, when organically fertilized, the forage mixtures produced comparatively high crude protein and fiber fractions. Keeping in view the above facts, this study was planned with the objective to get maximum fodder yield and good quality of berseem sown in combination with different proportions of other forage (oats, sarson, barley, haalun and ryegrass) crops.

Materials and Methods

Location of experiment

The experiments were carried out at field area of Agronomy Section (Forage Production), Ayub Agricultural Research Institute, Faisalabad in order to investigate the productivity and forage quality of berseem sown in pure stands and mixed in different proportion of ryegrass, barley, oats, sarson and haalun. The experimental site is situated at latitude 31.45° N and Longitude 73.13° E. Physio-chemical properties of the experiential site for both seasons (2019-20 & 2020-21) are given in Table 1. Soil was loamy during both years. Monthly weather data during growth period for both years is presented in Table 2. Rainfall was more and more well distributed during the year 2019-20 than the year 2020-21. Maximum temperature remained comparatively lower during the growing period of the crops for the year 2019-20 than the year 2020-21.

Table 1 Physico-chemical analysis of experimental soil (0-30 cm)

Soil analysis	2019-2020	2020-2021
Physical analysis		
Sand	40.69	41.64
Silt	42.93	41.95
Clay	16.38	16.35
Textural class	Loam	Loam
Chemical analysis		
PH	8.7	8.6
Total soluble salts	0.22	0.21
Organic matter	0.43	0.38
Available P (ppm)	10.5	10.2
Potassium K (ppm)	390	388

Table 2 Monthly mean weather attributes during growth period of the crops

Months	Max. temp. (°C)		Min. temp. (ºC)		Relative humidity (%)		Rainfall (mm)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
October	32.9	35.0	18.9	17.0	78.4 (8 a.m.) 50.8 (5 p.m.)	66.1 (8 a.m.) 37.7 (5 p.m.)	22.4	-
November	26.1	26.3	12.8	10.2	82.2 (8 a.m.) 55.4 (5 p.m.)	81.5 (8 a.m.) 53.5 (5 p.m.)	3.0	0.8
December	17.0	21.0	6.0	6.5	87.0 (8 a.m.) 67.0 (5 p.m.)	84.9 (8 a.m.) 59.5 (5 p.m.)	7.0	2.3
January	17.3	17.5	5.5	5.5	88.3 (8 a.m.) 60.3 (5 p.m.)	89.2 (8 a.m.) 64.5 (5 p.m.)	50.8	56.5
February	23.8	25.9	8.7	9.8	83.4 (8 a.m.) 46.4 (5 p.m.)	80.8 (8 a.m.) 40.0 (5 p.m.)	24.8	-
March	24.2	26.4	13.9	14.2	78.5 (8 a.m.) 60.9 (5 p.m.)	78.3 (8 a.m.) 60.3 (5 p.m.)	135.0	82.6
April	33.1	34.5	18.8	18.4	69.7 (8 a.m.) 51.7 (5 p.m.)	52.4 (8 a.m.) 33.2 (5 p.m.)	20.4	15.4

Source: Meteorology Section, Agronomic Research Institute, Faisalabad

Treatments and design

The experiment was executed in randomized complete block design (RCBD) with four replications during the years 2019-20 and 2020-21. Sorghum was sown as a prevision crop during both years Soil was prepared by two cultivations followed by one planking. Field was irrigated fortnightly till March, then weekly up till the last cut. Seed @ 20 kg ha^{-1} of berseem, 80 kg ha^{-1} of oats, 5 kg ha^{-1} of sarson, 90 kg ha^{-1} of barley, 8 kg ha^{-1} of haalun and 15 kg $ha^{-1}$of ryegrass were used as per pre-calculated ratio. Fertilizer @ 70-100-30 NPK kg ha^{-1} was applied. The Berseem variety 'Super Berseem' was used as a base crop. The treatments were Berseem 100%, Berseem 75% + Oats 25%, Berseem 75% + Sarson 25%, Berseem 75% + Barley 25%, Berseem 75% + Haalun 25%, Berseem 75% + Ryegrass 25% and Berseem 50% + Oats 10%+ Sarson 10% + Barley 10% + Haalun 10% + Ryegrass 10 %. The crops were sown on 9th October 2019 and 12th October 2020. First cut was taken on 26th December during both years while subsequent cuts were taken on 15th February, 22nd March, 26th April during the year 2020, and 17th February, 25th March, 28th April during the year 2021.

Data recording

Data on plant height of berseem, number of tillers m^{-2} of berseem and number of leaves $plant^{-1}$of berseem were recorded while data on crude protein, crude fiber and green fodder yield of mixture were recorded. Four cuts were taken during both years. Data on plant height, number of tillers m^{-2} and number of leaves $plant^{-1}$of berseem were pooled and then averaged, while data on green fodder yield of mixture were clubbed together.

Statistical analysis

The collected data were subjected to analysis of variance (ANOVA) by using Statistix 8.1 procedure. The treatment mean differences were compared by using LSD test at 5% level of probability (Steel et al., 1997).

Results

Plant height of berseem (cm)

Regarding plant height of berseem, berseem sown alone or in all combinations produced plant height statistically at par with each other, showing there by no effect of companion crops on plant height of berseem (Table 3).

Number of tillers m^{-2} of berseem

Intercropping showed a significant influence on the number of tillers m^{-2} of berseem. Maximum tillers m^{-2} of berseem (124.67) were observed when berseem was sown alone, while minimum tillers m^{-2} of berseem were observed when 75% berseem mixed with 25% ryegrass was sown, which was statistically at par with those of 75% berseem mixed with 25% haalun and 50% berseem mixed with 10% oats, 10% sarson, 10% barley, 10% haalun and 10% ryegrass (Table 3).

Table 3 Yield components of berseem sown alone and in combination with other crops (2-year average)

Treatments	Plant height (cm)	No. of tillers m^{-2}	No. of leaves $plant^{-1}$
Berseem 100 %	55.00	124.67^{a}	33.50^{a}
Berseem 75 % + Oats 25%	51.83	112.00^{b}	26.50^{b}
Berseem 75 % + Sarson 25%	52.50	109.00^{bc}	25.50^{b}
Berseem 75 % + Barley 25%	53.00	105.83^{cd}	24.00^{b}
Berseem 75 % + Haalun 25%	52.83	104.17^{de}	25.00^{b}
Berseem 75 %+ 25% Ryegrass	51.06	101.00^{e}	26.00^{b}
Berseem 50 %+ Oats 10 %+ Sarson 10 %+ Barley 10 %+ Haalun 10 %+ Ryegrass 10 %	52.17	101.67^{de}	26.50^{b}
LSD (0.05)	NS	4.45	4.27

*Means followed by different letter(s) are significantly different, NS = non-significant

Number of leaves per plant of berseem

Regarding the number of leaves per plant of berseem, intercropping showed a significant effect on the number of leaves per plant of berseem. Significantly the highest number of leaves of berseem was recorded when berseem was sown alone (100% berseem), whereas berseem sown in all mixtures produced a statistically similar number of leaves (Table 3).

Relationship between number of leaves and number of tillers of berseem

Highly significant correlation between these two traits (R = 0.847, p-value = 0.01) and regression (R^2 = 0.717) were found (Fig. 1), showing thereby that number of leaves increased when more tillers were produced.

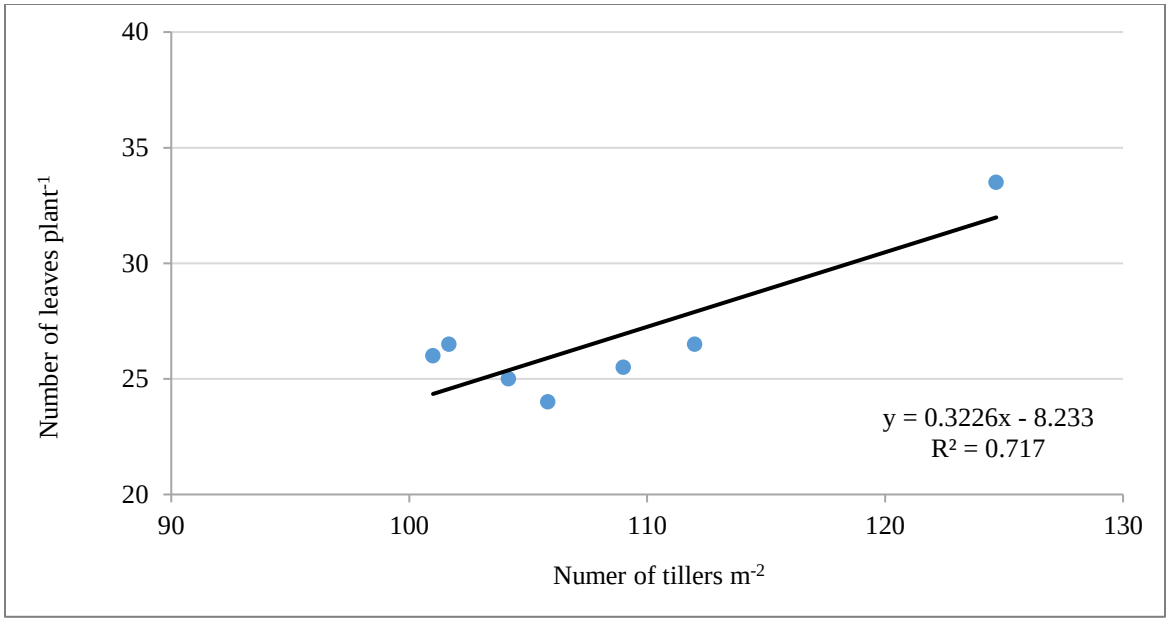

Fig. 1 Correlation between leaves plant^{-1} and tillers m^{-2} of berseem sown alone and in combination with other crops

Green fodder yield (kg ha^{-1})

Regarding green fodder yield, overall maximum green fodder yield (136.58 t ha^{-1}) was observed in plots where 75% berseem mixed with 25% oats were sown, which was significantly highest to those of berseem sown alone and all mixtures. It was followed by those (129.83 t ha^{-1}) where 75% berseem with 25% barley were sown (Table 4). Minimum green fodder yield (104.75 t ha^{-1}) was recorded where sole berseem (100 %) was sown.

Table 4 Total green fodder yield, crude protein and crude fiber of berseem alone and mixtures (2-year average)

Treatments	Green fodder yield (t ha^{-1})	Crude protein (%)	Crude fiber (%)
Berseem 100 %	104.75^{f}	19.23^{a}	16.03^{g}
Berseem 75% + Oats 25%	136.58^{a}	17.53^{bc}	20.13^{d}
Berseem75 % + Sarson 25%	114.42^{d}	17.70^{b}	17.46^{f}
Berseem 75% + Barley 25%	129.83^{b}	15.87^{d}	24.63^{a}
Berseem75% + Haalun 25%	108.42^{e}	15.56^{d}	18.83^{e}
Berseem 75%+ Ryegrass 25%	125.00^{c}	18.11^{b}	23.36^{b}
Berseem 50% + Oats 10% + Sarson 10%+ Barley 10% + Haalun 10% + Ryegrass 10%	123.50^{c}	16.50^{cd}	21.50^{c}
LSD (0.05)	3.67	1.08	1.14

*Means followed by different letter(s) are significantly different

Increase of green fodder yield of mixtures over berseem sown alone

A 30.4% increase in green fodder yield was observed when 75% berseem was sown with 25% oats, and 23.9% increase when sown with 25% barley (Table 5). This showed that yield of first and second cut enhanced significantly when berseem was mixed with oats or barley. Oats mixed with berseem produced 38.35 and 37.40 t ha^{-1} in first and second cuts which were significantly higher than those of other combinations (Fig. 2). Similar was the case with barley mixed with berseem by producing 35.25 and 34.92 t ha^{-1} (Fig. 2). Ryegrass mixed with berseem produced almost similar yield during four cuts.

Table 5 Increase/ decrease of green fodder yield and protein content of mixtures over berseem sown alone

Treatments	Increase in fodder yield of mixture over berseem alone (%)	Decrease in protein of mixture over berseem alone (%)
Berseem 100%	-	-
Berseem 75% + Oats 25%	30.4	8.8
Berseem 75% + Sarson 25%	9.2	8.0
Berseem 75% + Barley 25%	23.9	17.5
Berseem 75% + Haalun 25%	3.5	19.1
Berseem 75% + Ryegrass 25%	19.3	5.8
Berseem 50% + Oats 10% + Sarson 10% + Barley 10% + Haalun 10% + Ryegrass 10%	17.9	14.2

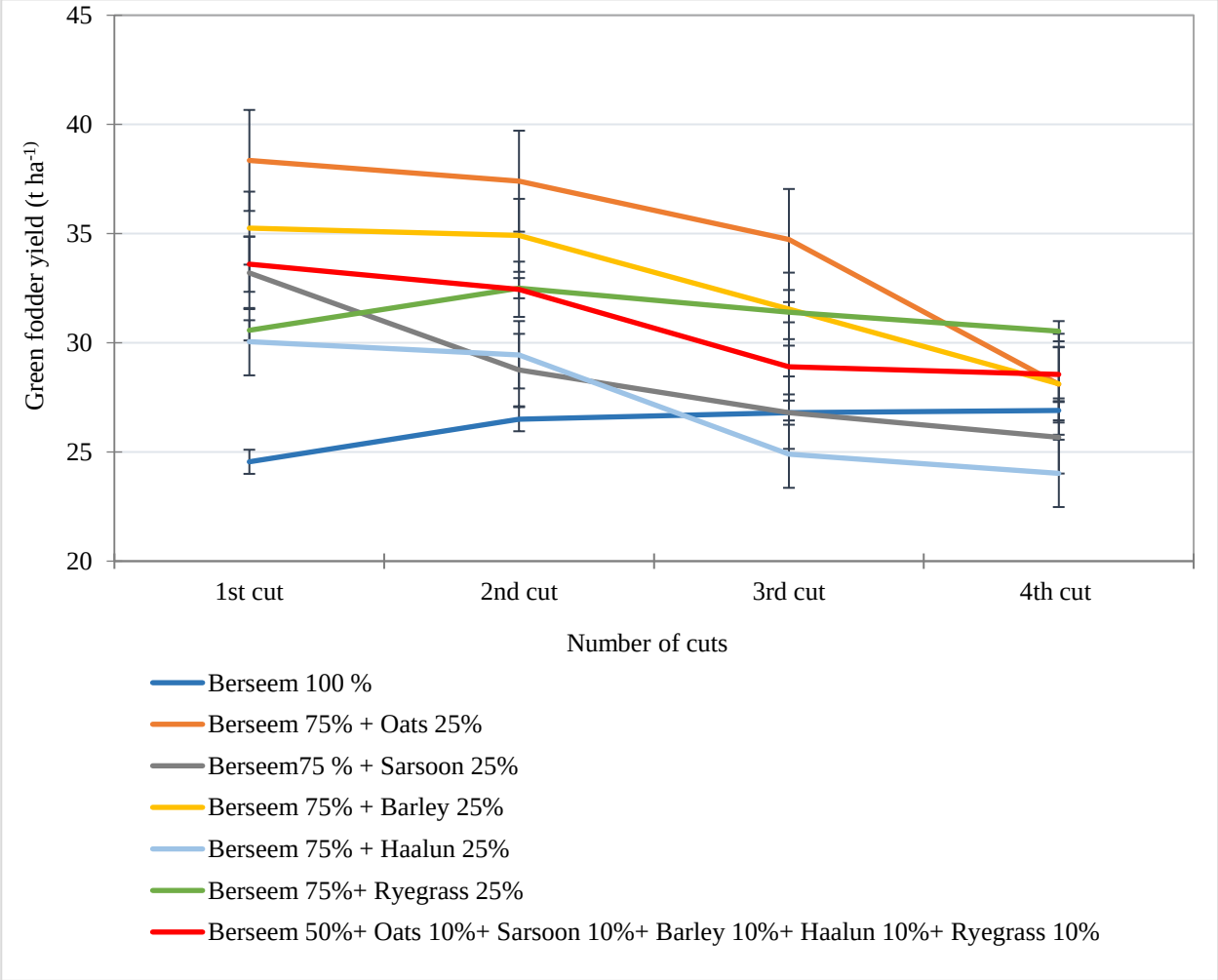

Fig. 2 Comparison of green fodder yield of four cuts of berseem sown alone and mixtures with other crops (2-year average)

Influence of temperature on green fodder yield

Overall, higher yield was observed during the first cut, which decreased in succeeding cuts. During first cut, average fodder yield was 32.22 t ha^{-1}, which decreased in the subsequent cuts i.e., 31.71, 29.30, 27.41, respectively (Fig. 3). The reason may be the rise in temperature during March-April, which decreased the yield of berseem (Fig. 3).

Crude protein content (%)

Significantly highest crude protein contents (19.23 %) were observed where berseem was sown alone. It was followed by 75% berseem mixed with 25% ryegrass or 25% sarson or 25%

oats, which were statistically at par with each other (Table 4). Minimum crude protein contents were observed when 75% berseem was sown with 25% barley or 25% haalun. Data on protein content was taken at first cut. Decrease in protein content of mixtures compared with berseem sown alone ranged 5.8 - 19.1% (Table 5).

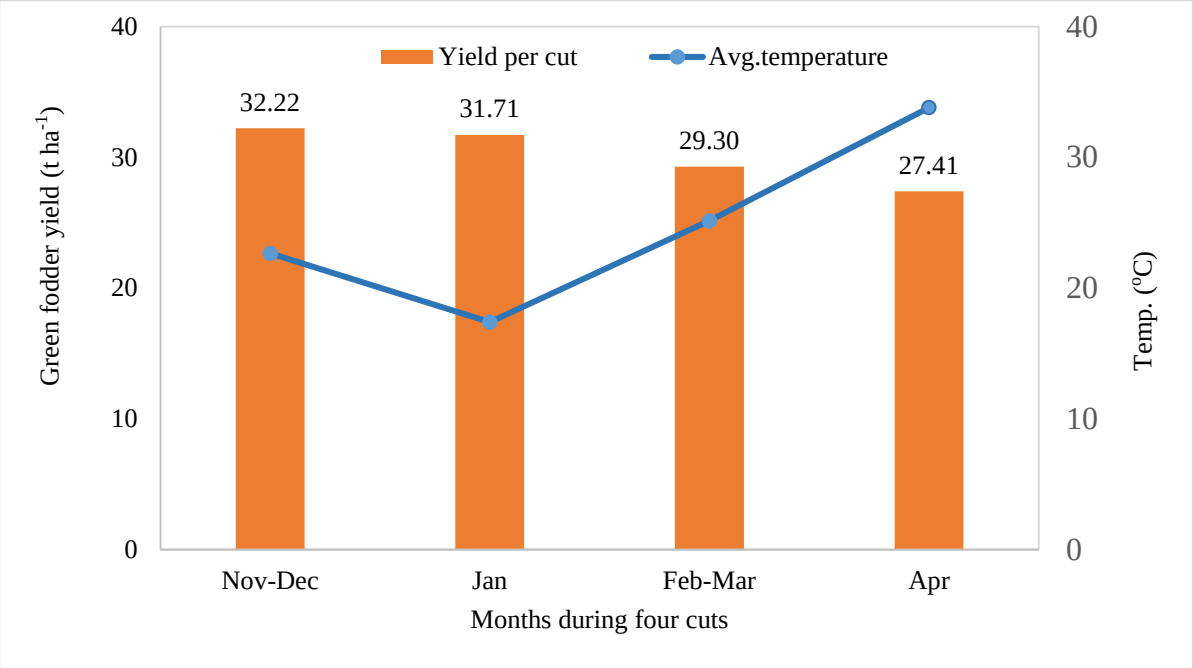

Fig. 3 Average green fodder yield of four cuts influenced by mean temperature (2- year average)

Crude fiber (%)

Significantly maximum crude fiber (24.63%) was observed in plots where berseem 75% + barley 25% was sown. It was followed by berseem 75% + ryegrass 25% (23.36%), while minimum crude fiber was recorded in plots where 100% berseem was sown (Table 4).

Discussion

Statistically similar plant height of berseem was observed either sown alone or in combination with other crops but produced significantly more numbers of tillers per unit area when berseem was sown alone. This showed that companion crops did not affect the plant height of berseem. It was also observed that the number of tillers per unit area increased during the subsequent cuts, but plant height remained almost similar during all cuts. It showed that berseem utilized the space after first cut in producing tillers instead of plant height. It further revealed that being alone, berseem utilized the benefits of space in terms of tillers instead of plant height.

Similar was the case with the number of leaves per plant. More number of tillers of berseem produced a significantly higher number of leaves of berseem when sown alone as well after first cut. It showed that berseem sown alone got the benefit of ground area and produced more tiller per unit area, which ultimately resulted in producing a greater number of leaves per plant. Similarly, Capstaff and Miller (2018) opined that not only plant height but also ground area cover were imperative to assess yield.

Increase in green fodder yield of plots sown with 75% berseem and 25% oats (30.4%) and of plots sown with 75% berseem and 25% barley (23.9%) showed that yield of first and second cut enhanced significantly when berseem was mixed with oats or barley. Oats mixed with berseem produced 38.35 and 37.40 t ha^{-1} in first and second cuts which were significantly higher than those of other combinations. Similar was the case with barley mixed with berseem by producing 35.25 and 34.92 t ha^{-1}. Ryegrass mixed with berseem produced almost similar yield during four cuts because of its growing habit i.e., it contributed to yield in all cuts. It is due the fact that oats and barley regenerate to some extent after first cut, whereas rye grass contributes fodder yield in all four cuts with berseem. These results are in line with the conclusion drawn by El-Karamany et al., (2014) who reported that despite the protein content of berseem being high, it is considered to have low dry matter content particularly in the first cut.

Similarly, Abdel-Aziz et al., (2007) reported a significant variation in green fodder yields of berseem – ryegrass mixed cropping. They further explained that this variation was due to the nitrogen fertilizer rates and ryegrass seeding rate. They recorded the highest green fodder yield when a mixture of berseem @ 20 kg and ryegrass @ 12 kg were sown, while berseem sown alone had the minimum green fodder and dry matter yield. Thus, mixing berseem with forage grasses is a low input technology that has many beneficial effects on forage productivity and nutritive value. Same reason might be

inferred in case of berseem mixed with barley with the same proportion as in treatment of berseem mixed with oats because barley also contributed in first as well as second cut of berseem. Ross et.al., (2004) revealed that intercropping of berseem with ryegrass, oats or barley improved forage quality and yield. Likewise, findings of Salama (2020) indicated that mixtures of berseem clover with triticale at proportion of 75%:25% produced the highest forage yield with improved quality than all other mixtures. Bacchi et al., (2021) concluded in their study that total fodder yield of all intercrops was much higher than those of legumes. They argued that available resources were better utilized in complementary ways by intercrops because of no competition of intercropped species for the same niche areas. Therefore, intercropping adoption granted farmers to improve forage quality and yield. They suggested that ryegrass and triticale intercropped with peas and vetch is recommended provided green fodder is needed with good nutritional value, but barley and triticale mixed with vetch or peas should be used if silage fodder is considered.

Benefits of the mixture consist of increasing dry matter yields, which is primarily due to the benefit of the companion grass from nitrogen fixed by the legume. This benefit is a result of nitrogen transfer, developing protein content and producing nutritious forage (Capstaff and Miller, 2018). It is worth to note that minimum green fodder yield (104.75 t ha^{-1}) was recorded where berseem alone (100 %) was sown. This was due to low yield of the first cut of berseem that affected the overall yield. Fodder yield during 2019-20 was observed slightly higher than that during 2020-2021. This may be due to more rainfall during the growth period in the year 2019-20 than that of the year 2020-21. It kept comparatively higher relative humidity and less maximum temperature in 2019-2020 than the year 2020-21. It was further noted that overall higher yield was observed during the first cut, which decreased in succeeding cuts. This was due to the contribution of other companion cops mixed with berseem during the first cut. Ross et al., (2004) also concluded that cereal in intercropped plots dominated the yield in first cut but berseem dominated regrowth yield in succeeding cuts. Another reason may be the rise in temperature during March-April, which decreased the yield of berseem.

Data on protein content was taken at first cut. Decrease in protein content of mixtures compared with berseem sown alone ranged 5.8 - 19.1%. This was due to the high protein content of berseem as compared to all other crops used in combination. Another factor might be the ability of berseem to fix nitrogen being a legume crop. Bingol et al., (2007) found that the mixture of barley and vetch had significantly higher digestible dry matter and crude protein yield. Strydhorst et al., (2008) reported that legumes intercropped with barely resulted in higher forage quality than pure barley. Also, forage quality in terms of Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) was improved by mixed sowing of grass with annual legumes (Salama, 2015). Results of another study done by Salama (2020) clearly indicated that mixing rate significantly influenced the yield and quality performances of grass-legume mixtures. Similarly, Lee (2018) also observed that herbaceous legumes had more protein content as compared to grasses. Likewise, Rodriguez et al., (2020) observed 13-16 % more proportion of nitrogen derived from symbiotic nitrogen fixation in intercropped grain legume than sole legume crop, while total soil nitrogen gain (mixture of legume and cereal) was significantly higher in intercrops than in sole legume crops. They further argued that legume cereal intercropping improves nitrogen usage during the growing period, due to complementary functioning in which a greater amount of available soil nitrogen is recovered by cereals. These results revealed that intercropping consistently enhanced the resilience of nitrogen fixation.

Likewise, Abdel-Aziz et al. (2007) observed the highest crude protein content when mixed crops of berseem and ryegrass were sown at seeding rate of 20 kg berseem + 8 kg ryegrass. On the contrary, Lavergne et al., (2021) narrated that sowing of mixed crops showed no clear advantage over field peas sown alone in terms of nitrogen supply to the subsequent maize crop. They further argued that links between crop decay and associated soil nitrogen dynamics resulting from pure legume and legume-based mixture need more attention. Seed rate and seed proportion in mixture also need to be considered to get maximum shoot biomass. Jensen et al., (2020) reported that using ^{15}N isotope techniques, the cereal crop in cereal-legume intercropping system utilized a higher proportional share of soil nitrogen sources due to complementary nitrogen acquisition and competitive interactions in intercrops. As a consequence, more nitrogen is fixed by legumes grown as intercrop compared with that grown as sole crop. They estimated that the requirement for nitrogen fertilizer is lessened by about 26% on a global scale due to the increased nitrogen use efficiency in the intercropping system. In addition, they indicated that cereal-legume intercropping had additional advantages of increased yield per unit area, less requirements of fertilizers/ agrochemicals and lesser pest problems over sole cropping.

Similarly, data on crude fiber content was taken at first cut. Berseem sown alone produced the minimum crude fiber. This is due to the fact that grasses generally have more crude fiber. Lee (2018) was also with a view that grasses, on the average, contained more crude fiber. These findings were also reported by Abdel-Aziz et al. (2007). They observed the lowest crude fiber content where berseem was sown alone as compared to berseem sown in mixture with ryegrass.

Conclusion

It is concluded that 75% berseem mixed with 25% oats, or 75% berseem mixed with 25% barley is a better option to get more green fodder yield. So, it is recommended for farmers that berseem 75% + oats/barley 25% combination is more productive in quantitative terms, while qualitatively, berseem alone is the best option, particularly for mulching animals. The 75% berseem mixed with 25% ryegrass is another option to get relatively good yield as well as quality fodder.

Conflict of interest: The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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