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ROW SEEDING CONFIGURATION REGULATES YIELD, QUALITY AND COMPETITION IN COMMON VETCH (*Vicia sativa* L.)-SUDANGRASS (*Sorghum sudanense* (Piper.) Stapf.) MIXTURE

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ABSTRACT

Intercropping used in modern agricultural systems is designed for growing more plant species in the same field for maximized growth parameters. This study was conducted to understand the effects of row seeding configuration (same, alternate and cross seeding row) and different Sudangrass ratios (25 and 50%) on yield, quality, and competitive ability of common vetch in second crop production. Among row seeding configuration, same row seeding maximized the aboveground biomass production but decreased belowground biomass, crude protein content and NDF (Neutral Detergent Fiber). Plant height, ratio, ADF (Acid Detergent Fiber) content, AGRNE (Aboveground Relative Neighbor Effect), and BGRNE (Belowground Relative Neighbor Effect) were not affected by row seeding configurations. In order to maximize the utilization from the row seeding configuration, the same row seeding can increase the aboveground biomass but mitigate belowground biomass and crude protein content. The row seeding configuration may represent a potential for yield, quality, and competitive ability when sown as a mixture using 25% Sudangrass ratio.

Keywords: Competition, intercropping, quality, second crop, yield

INTRODUCTION

Mixed cultivation has been arranged in modern agricultural systems for improving yield and soil properties, and for decreasing biotic and abiotic stress factors. It represents competition, complementarity, cooperation, and compensation among plant species during the cropping cycle (Justes et al., 2021). Yield, quality, and competitive ability of a mixture can exceed or regulate by choosing the best performing species (Acar et al., 2006). The positive effects of mixed species on the productivity of a stand are different depending on the plant species, plant properties, diversity, and climatic conditions (Ergon et al., 2016). The balance among facilitation, competition, and neutral effect can occur due to climatic, edaphic factors, plant density, physiology, life stage, invasion, and plant species (Manea and Leishman, 2011). Except for minor differences in the requirement of plant species, they compete for the same resources such as water, nutrient, light, or space during the growth period. The facilitative effect is more common under high abiotic stress conditions (Bertness and Callaway, 1994). Some species can facilitate by altering the soil microbial diversity and by increasing nitrogen assimilation due to nitrogen fixation and by ameliorating the local environment (Ehlers et al., 2014; Dang et al., 2020), but indirect facilitation is more common among plants. In addition to the facilitative effect, there is a negative impact among plant species depending on allelochemical contents and leachate. These compounds can inhibit the germination and growth performance of plant species (Cook et al., 2010; Ehlers et al., 2014).

In mixed cropping, row seeding is one of the most effective factors for regulating plant-plant interaction. How intercropping advantages or disadvantages in mixture alters with different row seeding?. Alternate row seeding is often suggested as a technique to improve the establishment and life forms in separate rows, which may reduces row competition, but increases the species diversity of a planting. Different row seeding regulates plant-plant interaction and increases the yield and the land equivalent ratio (Erkovan et al., 2008), but its advantage is unclear in the common vetch-Sudangrass mixture for second crop production. Same rows seeding configuration have the disadvantage of increasing competition especially space, but it has the advantage of preventing common vetch from lodging. Seeding different life forms in alternate and cross-seeding row may reduce competition, improve stand establishment, and increase yield and quality due to increasing land equivalent ratio and using resources such as light, nutrient, water etc. (Pokorny et al., 2020; Justes et al., 2021). Kilcher and Heinrichs (1958) suggested that seeding methods performed better or less than mixed cropping of alfalfa in terms of yield and competition. But Yolcu (2005) reported that same, alternate, and cross-seeding rows of alfalfa and smooth bromegrass mixture did not affect dry matter yield. However, there are no detailed studies on row seeding of Sudangrass-common vetch intercropping, especially on the second forage cropping.

In Turkey, especially Mediterranean Climate Zone, second crop production has an important role in improving forage production. Common vetch is the second most grown crop after alfalfa in Turkey, and has been successfully used in this zone. There is a disadvantage of common vetch cultivation as a cool season forage crop in the second crop growing period because of high temperature. This disadvantage of common vetch can be tolerated by growing in a mixture with warm-season plant species. Forage yield increases by choosing the best performing and sowing ratio of plant species (Ergon et al., 2016). The positive or negative effect of the sowing ratio on yield and yield components depends on the mutualistic interaction of species and environmental properties. For example, rapidly growing Sudangrass under high temperature and drought conditions creates a microclimate environment for other plant species due to temporal niche differentiation and increases their yield (Poorter and Navas, 2003; Justes et al., 2021), but may inhibit plant growth as it has allelopathic compounds (Cook et al., 2010). The positive effect of the sowing ratio on yield and yield components of mixtures occurs under various climatic conditions depending on plant species functional characteristics (Kavut and Geren, 2017; Ergon et al., 2016). Sudangrass is generally more competitive in mixtures with short plant species because of temporal niche differentiation, light conservation, water use efficiency, nutrient acquisition, etc. Hence, Sudangrass is sown later than other plants or using decreased seed rate for less competition. Decreased ratio in mixed cropping systems is known as an important strategy for plant-plant interactions (Koc et al., 2013).

Common vetch and oat, barley, wheat mixed cropping has been widely studied at different seeding ratios, harvest and sowing time to assess the performance yield, quality, and fertilizer use efficiency in the region (Dereli, 2015; Kavut et al., 2016; Ileri et al., 2020; Ileri et al., 2021). There are some problems, especially short growing season and wide temperature range conditions (Mazzafera et al., 2021). However, less attention has been given to sowing methods, row seeding, life form, plant height, canopy structure, and at the second crop production. The objectives of this study are to determine the effects of row seeding configurations in the common vetch-Sudangrass mixture for better yield, quality, and the less competitive effect between common vetch and Sudangrass, when the ratio of Sudangrass was reduced by 50 and 75% in the mixture.

MATERIALS AND METHODS

The field experiment was conducted during 2019 and 2020 after harvesting wheat in the second crop growing season at the experimental station of Eskisehir Osmangazi University, Faculty of Agriculture. The long-term average annual air temperature of experimental area was 12.8 ^{0}C, and nearly 180 days that were frost-free in a year. The monthly temperature of the experimental years in 2019 and 2020 were 12.3 and 13.0 ^{0}C, respectively (Table 1). The mean annual precipitation for the long term, 2019 and 2020 were 352.4 mm, 405.5 mm, and 299.2 mm, respectively (Table 1). The experimental soil characteristics were determined as described by Soil Survey Laboratory Staff (1992), and clay-loam in texture, slightly alkaline, lime, and organic matter contents were 14.6% and 1.62% (poor) respectively. Soil salinity level was quite low (0.07 %) and P_2O_5 and K_2O contents were 61.6 and 1688.0 kg ha^{-1} respectively.

Table 1. Climatic data for the study site, temperature (°C), monthly precipitation (mm) and humidity (%) during 2019 and 2020 and the long-term average (LTA; 1929–2020).

Months	Temperature (^{0}C)			Precipitation (mm)			Humidity (%)		
	2019	**2020**	**LTA**	**2019**	**2020**	**LTA**	**2019**	**2020**	**LTA**
January	4.3	0.3	0.3	60.2	52.7	38.7	91.0	78.7	98.2
February	3.4	4.1	4.7	50.1	43.3	32.5	79.6	70.8	92.6
March	6.3	8.2	9.3	13.4	20.0	33.4	64.5	63.5	81.6
April	9.5	10.9	13.1	26.7	13.0	35.0	69.3	57.2	67.8
May	16.5	16.3	16.5	42.2	38.9	44.8	65.1	58.0	86.1
June	20.9	19.5	20.4	45.7	74.3	30.6	67.9	63.5	83.3
July	**21.3**	**23.2**	**23.3**	**33.5**	**1.2**	**14.0**	**62.3**	**58.0**	**75.8**
August	**22.3**	**23.4**	**22.9**	**2.4**	**1.0**	**7.8**	**61.0**	**52.1**	**74.1**
September	**18.1**	**21.5**	**20.0**	**5.0**	**6.0**	**14.4**	**62.1**	**59.9**	**68.1**
October	**14.2**	**16.1**	**12.9**	**18.3**	**37.6**	**27.0**	**70.1**	**73.8**	**79.6**
November	7.9	6.3	7.5	33.9	1.4	29.2	76.2	72.7	80.3
December	2.9	5.7	3.6	74.1	9.8	45.1	89.9	77.2	93.6
Tot./Ave.	***12.3***	***13.0***	***12.8***	***405.5***	***299.2***	***352.4***	***71.6***	***65.5***	***81.8***

Bold lines: Growing season for the experiment

Common vetch (cv. Orakefe) and Sudangrass (cv. Gozde-80) were used as plant materials. The field trial was arranged in the Randomized Complete Block Design (RCBD) with 3 replications. Common vetch was sown at the 120 kg ha^{-1} (Acikgoz, 2001) and was mixed with Sudangrass by reducing the seeding rates as 50% (5 kg ha^{-1}) and 75% (2.5 kg ha^{-1}) considering the suggestions as 10 kg ha^{-1} for Sudangrass.

Plants were sown on 04 and 21 June in 2019 and 2020 years respectively depending on the wheat harvest in the region. All plots were 5 m of 1.5 m at different row seeding and Sudangrass sowing ratios. Common vetch was seeded as sole crop or as a mixture with Sudangrass. While common vetch and Sudangrass were seeded in 5 same rows 0.3 m spaced rows, they were separately seeded in alternate 0.15 m spaced rows between common vetch and Sudangrass, and in cross-seeding row 0.3 m spaced. Nitrogen (30 kg ha^{-1}) and phosphorus (70 kg ha^{-1} P_2O_5) were applied as Di-ammonium phosphate (DAP) and irrigation was applied every week using sprinkler and considering the requirement of the plants. Weed control was done by hand hoeing within the plots.

The harvest stage was determined considering in the lowest pods full set stage of common vetch as suggested by Kusvuran et al. (2014) and all plants were harvested together with the common vetch. The harvest date was 23 September and 14 October in 2019 and 2020 respectively. All plants were harvested in plots by cutting after taking out the 0.5 m from beginning and end of each row. Samples dried at 70 ºC until reached to constant weight at the oven to determine the aboveground biomass production. Root biomass was sampled in the same area of the plots after harvest. Excavated roots were firstly washed to separate from soil and dried at 70°C until reached to constant weight to determine the belowground biomass. Aboveground biomass samples were grounded to pass through a 2 mm sieve to determine crude protein (CP) content using the Kjeldahl method. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were determined due to the detergent method suggested by Van Soest et al. (1991). Relative neighbor effects of above-and belowground (ARNE and BRNE) among the mixed-species were determined using above-and belowground biomass production as in the formula that given by Oksanen et al. (2006).

$$RNE = (X_m – X_c) / Max (X_m \text{ or } X_c)$$

RNE; Relative neighbor effect, X_m; production in mixed sowing, X_c; production in sole

The analysis of variance was performed considering the General Linear Model (GLM). All data were tested for homogeneity and the variances were analyzed in terms of the completely randomized block design using SAS statistical software (SAS Institute, 2011). The means of treatments were compared by using the Bonferroni/Dunnett test.

RESULTS AND DISCUSSION

There was a significant difference in plant height among main factors and Sudangrass density x row seeding configuration interaction (Table 2). Common vetch sole sown height was higher at 2019 than in 2020 year (Table 2). Increasing the Sudangrass ratio from 25% to 50% in the mixture raised the plant height of common vetch from 48.38 cm to 52.38 cm ($p<0.0001$) (Table 2) (Figure 1). The plant height of sole growing common vetch was significantly higher than different row seeding configuration mixtures with Sudangrass ($p<0.001$), but there were no significant differences among the row seeding configurations (Table 2).

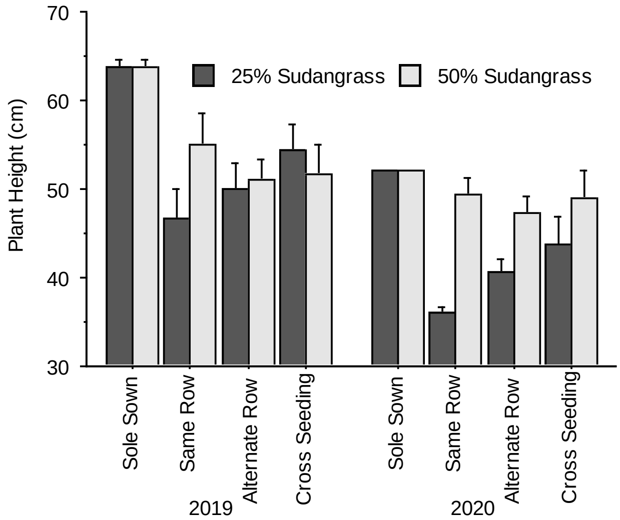

Figure 1. Plant height (± SE) in Sudangrass density and row seeding configuration during 2019 and 2020 sampling periods.

Overall common vetch ratio was 87.28% and it did not significantly vary between the years and among the Sudangrass densities (p<ns). The first and second-order interactions were not significant (Table 2). Common vetch ratio was higher in sole sowing than in other row seeding configurations mixture with different Sudangrass ratio ($p<0.0001$) (Table 2).

Aboveground biomass of common vetch and Sudangrass mixture was significantly affected by main factor year ($p<0.0001$), row seeding configuration ($p<0.0001$), and first and second-order interactions ($p<0.049$) except for main factor Sudangrass ratios (Table 2). Aboveground biomass was higher in the second year of the study (3956.4 kg ha^{-1}) and the highest value was determined in the same row seeding configuration (3902.8 kg ha^{-1}) while it was the lowest in the sole sowing of common vetch (2860.4 kg ha^{-1}) (Table 2) (Figure 2).

Except for the main factor Sudangrass ratio and second-order interaction (p<ns), years ($p<0.0001$), row seeding configuration ($p<0.0001$) and first order interaction ($p<0.049$) led to significant changes in belowground biomass production (Table 2) (Figure 3). Belowground biomass was found to be significantly higher in the second year (799.4 kg ha^{-1}) compared to the in the first year (658.3 kg ha^{-1}). On the other hand, cross-seeding and alternate row seeding configuration led to significantly higher belowground biomass than the other row seeding configurations (Table 2).

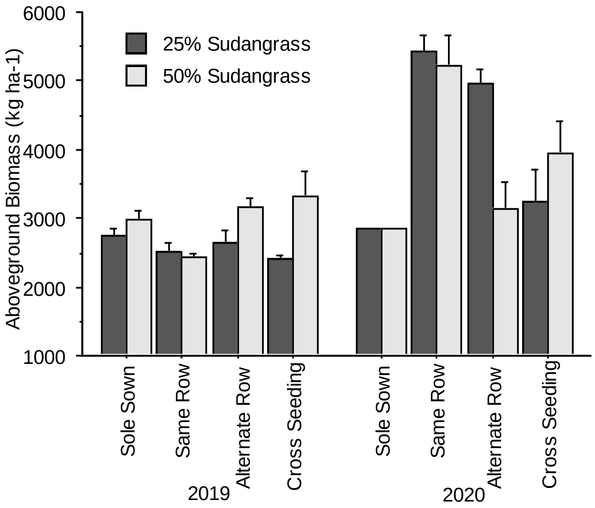

Figure 2. Aboveground biomass (± SE) in Sudangrass density and row seeding configuration during 2019 and 2020 sampling periods.

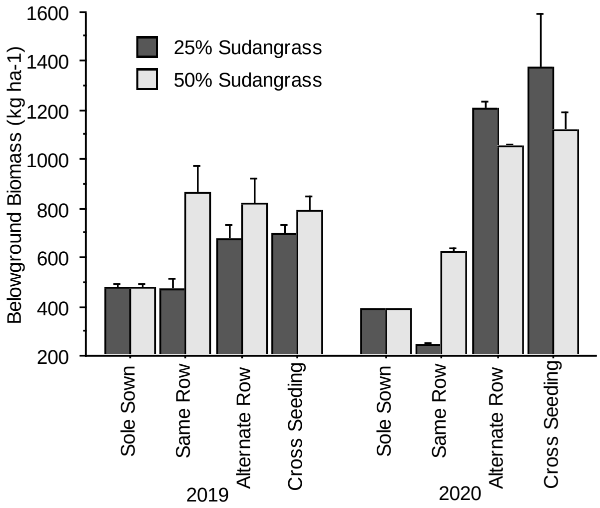

Figure 3. Belowground biomass (± SE) in Sudangrass density and row seeding configuration during 2019 and 2020 sampling periods.

Table 2. The results of analysis of variance (ANOVA) with main effects, first and second order interactions of Sudangrass ratio and row seeding configuration on plant height, common vetch ratio, above and belowground biomass, crude protein content, neutral detergent fibre (NDF), acid detergent fibre (ADF), above (AGRNE) and belowground (BGRNE) relative neighbour effect.

	Plant Height	Ratio	Aboveground Biomass (kg ha^{-1})	Belowground Biomass (kg ha^{-1})	Crude Protein (%)	NDF	ADF	AGRNE	BGRNE
Year (Y)									
2019	54.50 A	89.16	2781.0 B	658.3 B	14.04 B	41.89 A	33.18	-0.006 A	-0.185 A
2020	46.25 B	85.40	3956.4 A	799.4 A	16.93 A	34.97 B	32.91	-0.716 B	-0.876 B
Sudangrass Ratio (SR)									
25% Sudangrass	48.38 B	86.35	3353.3	691.2	15.47	38.94 a	33.25	-0.349	-0.537
50% Sudangrass	52.38 A	88.21	3384.1	766.6	15.49	37.92 b	32.83	-0.373	-0.524
Row Configuration (R)									
Sole	57.83 A	100.00 A	2860.4 C	434.5 C	14.66 B	38.63 A	33.12	-	-
Same Row	46.75 B	81.82 B	3902.8 A	549.1 B	14.45 B	39.06 A	33.16	-0.399	-0.416
Alternate Row	47.25 B	83.54 B	3478.8 B	938.3 A	16.10 A	39.15 A	32.98	-0.292	-0.582
Cross-seeding	49.67 B	83.76 B	3232.9 B	993.6 A	16.73 A	36.88 B	32.91	-0.391	-0.594
Mean	**48.40**	**87.28**	**3368.7**	**728.9**	**15.49**	**38.43**	**33.04**	**- 0.361**	**- 0.531**
Y	***	ns	***	***	***	***	ns	***	***
SR	**	ns	ns	ns	ns	*	ns	ns	ns
R	***	***	***	***	***	***	ns	ns	ns
Y x SR	ns	ns	**	***	ns	ns	ns	ns	ns
Y x R	ns	ns	***	*	***	**	ns	ns	ns
SR x R	*	ns	**	***	ns	**	ns	ns	ns
Y x SR x R	ns	ns	*	ns	*	***	ns	*	ns

Values followed by small and capital in a column shows significantly differences at P< 0.05 and P< 0.01 levels. ns: No statistical difference at P<0.05 and P<0.01. *Statistical difference at P< 0.05. **Statistical difference at P< 0.01. *** Statistical difference at P< 0.001.

Crude protein content was significantly affected by year (p<0.0001) and row seeding configuration (p<0.0001) (Table 2). Alternate and cross-seeding row seeding configuration positively affected crude protein content compared to sole and same row seeding configuration (Table 2). Crude protein content showed a variation depending on the year, Sudangrass ratio, and row seeding configuration. Hence, the second-order interaction was significant in the experiment (p<0.049) (Figure 4).

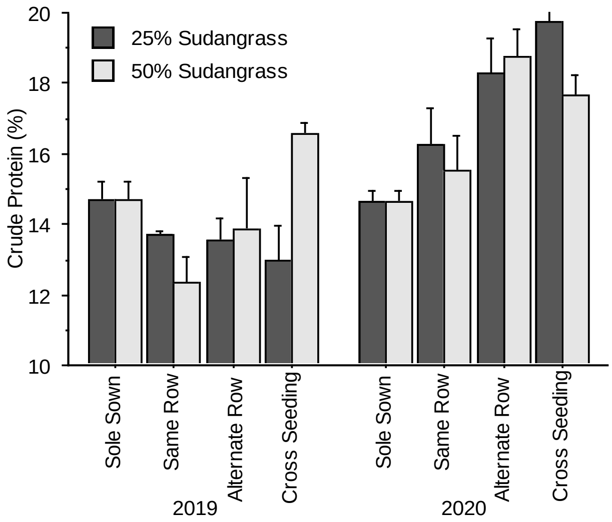

Figure 4. Crude protein content (± SE) in Sudangrass density and row seeding configuration during 2019 and 2020 sampling periods.

NDF content was significantly affected by main factors (p<0.049), first and second-order interactions (p<0.001) except for year x Sudangrass ratio interaction (Table 2). NDF content was higher in the first year (41.89%), and in the mixture with a 25% Sudangrass ratio (38.94%) (Table 2). Cross-seeding exhibited the significantly lowest NDF among row configurations (Table 2). There were significant variations in the NDF content. As a result of this, first and second-order interactions were significantly affected (Figure 5).

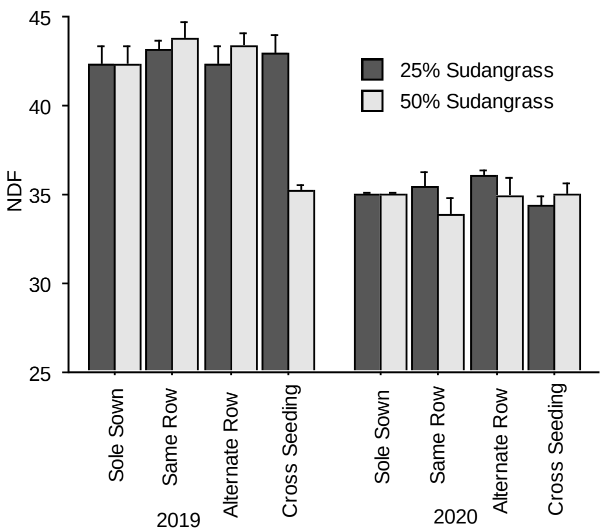

Figure 5. NDF content (± SE) in Sudangrass density and row seeding configuration during 2019 and 2020 sampling periods.

Overall ADF content was 33.04% and it did not significantly vary among the main factors, first and second-order interactions (Table 2).

The growth of the common vetch was significantly suppressed more than the second experiment year in competition with the Sudangrass diversity (p<0.0001) (Figure 6). There were no significant effects on the common vetch AGRNE first-order interactions; in contrast, there was significant effect of second-order interaction (Table 2). This was shown in the AGRNE, where Sudangrass ratio and row seeding configuration had a less positive effect in the first year, but more negative effect on the common vetch in the second year (Figure 6).

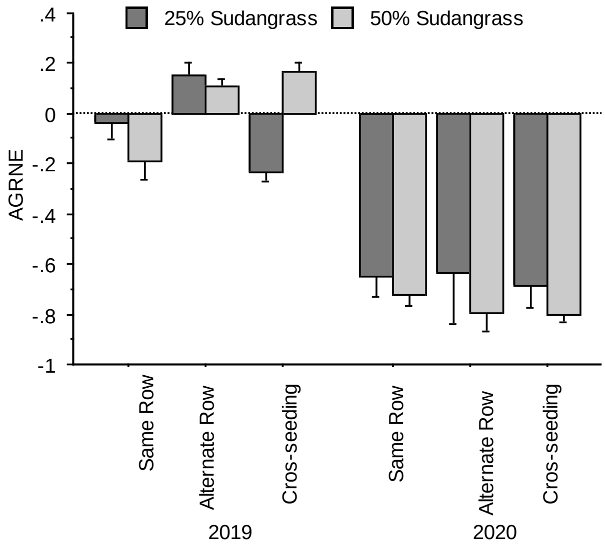

Figure 6. AGRNE (± SE) in Sudangrass density and row seeding configuration during 2019 and 2020 sampling periods.

Except for the year (p<0.0001), the main factors and the first and second-order interactions were not significant on BGRNE (Table 2). We found that common vetch BGRNE significantly suppressed more in 2020 than in 2019 (Table 2).

Crop production may be affected significantly by erratic weather conditions due to biotic and abiotic stress (Justes et al., 2021). The variability in weather conditions in the experiment years, especially temperature, played a deterministic role on plant height. It was higher in 2019 possibly due to cool-season characteristics of common vetch that the responses of climate conditions on growth properties have fully yet to be elucidated because of common phenomena of it (Lithourgidis et al., 2006; Baxevanos et al., 2021; Ileri et al 2021; Li et al., 2021). Intercropping resulted in a lower plant height in common vetch in comparison to the in sole grown, mainly due to the competition with Sudangrass. Similar results have been reported by Lavergne et al. (2021), Li et al. (2021). Common vetch was dominant within all mixtures and row seeding configuration and might have acted as different variations for each mixture.

Used plant species in the experiment have different sensitivities to climatic conditions. Common vetch (cool-season plant) grows better in cool conditions, while Sudangrass (warm-season plant) are more competitive in warmer conditions (Acikgoz, 2001). This shows that plant species had an advantage on interspecific competition when increasing temperature effects at second crops growing seasons. As a matter of fact, the plant height of common vetch was longer and both above and belowground less competed in 2019 that was cooler, but the above and belowground biomass has been lower because of the ratio and the growth performance of Sudangrass. In the second year of the experiment, the above and belowground biomass was higher because of increasing temperature and ratio of Sudangrass growth performance. Similar results have been reported by researchers (Ileri et al., 2021; Lavergne et al., 2021; Li et al., 2021). The sole stand of common vetch had lesser aboveground biomass about 1000 kg ha^{-1} compared to row seeding configurations, and the highest aboveground biomass was observed in the same row seeding. Alternate and cross-seeding rows did not increase the common vetch biomass production compared to same row seeding, but it is thought to reduce within row competition to improve stand establishment. Suitable mixtures due to niche complementarity of species increase the facilitative effect and aboveground biomass in the stand (Ergon et al., 2016). The helpful effects of symbiotic systems may facilitate increasing soil nutrient content, microbes, and radiation use efficiency in the mixture. Greater photosynthetic capacity, competition ratio, and radiation use efficiency increase aboveground biomass production in the row seeding configuration. Aboveground biomass production indicated a high magnitude variation in first and second-order interactions. This implies that the performance of plant species and row seeding configuration were less consistent in the mixture than two growing seasons (Baxevanos et al., 2021). Currently, the dominant plant of common vetch in the mixture was affected by the growth of Sudangrass, since the variation on aboveground biomass ranged within the year, Sudangrass ratio, and the row seeding configuration. The interaction taking place in mixtures is complex and occurs different during the growing seasons. The adoption of the mixture is challenging due to the short growing season and wide temperature range throughout the year. Consequently, these different responses of the common vetch to year, Sudangrass density, and row seeding configuration caused first and second-order interaction for aboveground biomass.

Although the proportion of Sudangrass in the composition was low in 2020, above and belowground biomass were more. The increase in belowground biomass in 2020 can be associated with substantial differences in temperature (Table 1). Belowground biomass mostly consisted of common vetch, whereas the ratio of Sudangrass belowground biomass was less. In 2019, lower belowground biomass can explain the fact that the growth of common vetch, which is a cool climate plant, was rapid and low productivity in the warmer period. Sudangrass presented a better growth performance in higher temperatures due to warm-season characteristics of the crop. As a result of this, competitive ability and productivity may change with the difference in temperature depending on the characteristics of the plant species (Dirks et al., 2021; Lavergne et al., 2021). Belowground biomass in the mixtures was more productive due to niche complementary and large contributions of plant roots. The sole grown common vetch produced the lowest belowground biomass compared to row seeding configurations, and also alternate and cross-seeding row configurations have greater belowground biomass than the same row seeding configuration. The greater belowground biomass could be explained by the contribution of mixtures. Because common vetch and Sudangrass roots properties and resource complementarity are different, hence complementarity increases when roots of common vetch or Sudangrass are away from zones of neighbors (Dirks et al., 2021). Common vetch and Sudangrass in alternate and cross-seeding row configurations may reduce competitive effects within the row due to decreasing competition for space, and their belowground performed increases (Koc et al., 2013), hence belowground biomass increases. The performance of common vetch belowground biomass production was less consistent over applications (years, density, and row configuration) than growing seasons. The differential responses of applications in the mixtures have not fully to be elucidated. Years and density-based variation of the interaction, which can be by the relative performance of different row seeding configurations. Likewise, the data of this study indicated the magnitude of interactions variation in comparison to the interactions for belowground biomass.

The crude protein content was affected significantly by years. The higher crude protein content was recorded the first year of the experiment. Generally, intercropping results in a variety of agronomic benefits along with improved crude protein content that in forage is the major criterion for forage quality appraisal. Legumes tend to improve the crude protein content of the mixture due to their higher protein content, also intercropping helps to a significant increase of crude protein content (Iqbal et al., 2019). The differences in climatic condition between the years affect growing condition, hence row seeding configuration effect on crude protein content changed depending on these factors (Table 1). The growing performance of the plant grown as sole or mixture had showed different performances depending on the differences between years (Carr et al., 2004; Pflueger et al., 2020). The crude protein content was significantly affected by row seeding configuration in the experiment. Row seeding configuration is often suggested as a technique to improve the establishment, yield, and quality (Tilley et al., 2008). Separate rows may decrease competition and may improve the establishment and the performance of plant species. Thus, the alternate and cross-seeding row had the highest crude protein content, whereas sole and same row showed the lowest crude protein content. The protein content of forage appears to be highly variable in genetically identical common vetch plants grown under the same conditions such as year, Sudangrass ratio, and row seeding configuration. Although there are some differences, mixtures showed partly consistent CP content among years, Sudangrass ratio, and row seeding configuration. This situation was the main reason for three-way interaction.

Year, Sudangrass ratio and row seeding configuration altered in the NDF content of the forage. The NDF contents were higher in the first year in the experiment. These might be related to increases in cellulosic component synthesis in the plant, because plant maturity plays a deterministic role in these contents (Erkovan et al., 2014; Kavut and Geren, 2017). Cross-seeding row conducted a significant decrease in NDF content compared to sole, same and alternate row, whereas the sole, same, and alternate row configuration did not show an interactive effect. Row seeding configuration is thought to reduce competition and heat stress to improve, warm weather causes generally an increase in cellulose content (Osman et al., 2010). Our findings implied that efficiency of year, Sudangrass ratio, and row seeding configuration are strongly related to climatic and competition condition that affects the availability of NDF content because the same treatment has a positive effect on NDF content due to increase cellulosic content.

In the summer, the high temperature could lead to greater competition between common vetch and Sudangrass due to several possible factors influencing the stability of plant species such as complementarity, resilience, and redundancy of plant species roles (Grant et al., 2014). Therefore, this could affect the above and belowground competition ability. Common vetch RNE performance decreased with increasing performance of Sudangrass. Because RNE can easily shift from competition to facilitation and vice versa that competitive intensity between common vetch and Sudangrass may be a key mechanism contributing to the stability of plant species under changing climate conditions. These results show the effect of climate and alterations in competitive ability including facilitation and competition among applications. Thus, competitive effects were occurred in the temperature due to increasing Sudangrass performance. As a result of this, AGRNE and BGRNE's competitive ability has increased in 2020 compared to 2019. These results showed the change of temperature, diversity, and induced alterations in competitive intensity including facilitation and competition in common vetch depending on the complexity of above and belowground relations. Consequently, these different responses of the common vetch to year, Sudangrass density, and row seeding configuration caused three-way interactions for AGRNE.

CONCLUSION

Our results showed a strong effect of the year on plant height, above and belowground biomass, crude protein, NDF, AGRNE, and BGRNE of common vetch as sole crop and mixture. The study shows that the seeding row seeding configuration of common vetch and Sudangrass mixture regulated some properties, but in the same row seeding aboveground biomass and NDF content was higher than other row seeding configurations. The same row seeding of common vetch with Sudangrass had an aboveground biomass production advantage for exploiting available resources, but alternate and cross-seeding row had an advantage for belowground biomass and crude protein content. This research indicates that row seeding configuration could have a significant effect on yield and quality when sown as a mixture using 25% Sudangrass ratio in the second crop conditions of semi-arid regions. These configurations of row seeding could provide economic and environmental benefits for sustainable production in the second crop season and further research is required to understand the net effect of root and canopy structure in various pedoclimatic conditions.

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