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Deldan Namgyal
Division of Agronomy FoA Wadura, SKUAST-K, Jammu and Kashmir, India

Amal Saxena
Division of Agronomy FoA Wadura, SKUAST-K, Jammu and Kashmir, India

D Namgyal
HMAARI Leh, SKUAST-K, Jammu and Kashmir, India

Rihanna Habib Kanth
Division of Agronomy FoA Wadura, SKUAST-K, Jammu and Kashmir, India

Fehim Jelani Wani
Division of Agri. Stat FoA Wadura, SKUAST-K, Jammu and Kashmir, India

Mohd. Ayoub Mantoo
Division of Entomology FoA Wadura, SKUAST-K, Jammu and Kashmir, India

MH Chesti
Division of Soil Science FoA Wadura, SKUAST-K, Jammu and Kashmir, India

Vikas Gupta
Division of Pathology FoA Wadura, SKUAST-K, Jammu and Kashmir, India

Nazir Hussain
Division of Agronomy FoA Wadura, SKUAST-K, Jammu and Kashmir, India

Tsultim Palmo
Division of Agronomy FoA Wadura, SKUAST-K, Jammu and Kashmir, India

Sonam Wangchok
KVK Leh, SKUAST-K, Jammu and Kashmir, India

Rigzin Safal
KVK Leh, SKUAST-K, Jammu and Kashmir, India

Nikhil Chandel
Division of Agri. Economics Shalimar, SKUAST-K, Jammu and Kashmir, India

Corresponding Author:
Deldan Namgyal
Division of Agronomy FoA Wadura, SKUAST-K, Jammu and Kashmir, India

Evaluation of fodder maize (*Zea mays* L.) and Rajmash (*Phaseolus vulgaris* L.) as intercrop for growth parameters of maize under cold arid Region of Ladakh

Deldan Namgyal, Amal Saxena, D Namgyal, Rihanna Habib Kanth, Fehim Jelani Wani, Mohd. Ayoub Mantoo, MH Chesti, Vikas Gupta, Nazir Hussain, Tsultim Palmo, Sonam Wangchok, Rigzin Safal and Nikhil Chandel

Abstract
The field experiment was conducted for two sessions during *Kharif* 2021 and 2022 at the experimental farm High Mountain Arid Agriculture Research Institute Leh of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir to study the "Evaluation of Fodder Maize (*Zea mays* L.) and Rajmash (*Phaseolus vulgaris* L.) as Intercrop for Growth Parameters of Maize under Cold Arid Region of Ladakh." The experiment incorporated simple random block design having 13 numbers of treatment having three replications: the technique of establishment (direct sowing and transplanting) and varied sowing dates with a 20-day interval. The treatment having Maize + Rajmash intercropping (2:6) at 20 cm row spacing found to be highest number of plant height at different interval of time, plant stand, number of leaves per plant, leaf length and leaf width. As a result, under Ladakh cold arid condition treatment having Maize + Rajmash intercropping (2:6) at 20 cm row spacing was determined to be a cost-effective way to increase fodder production in Maize.

Keywords: *Zea mays* L., parameters, *Phaseolus vulgaris* L.

Introduction
The search for very productive, long-lasting and environmentally friendly cropping systems is a contemporary theme in worldwide agriculture. Intercropping cereals and legumes is a well-known method for boosting productivity, quality and profitability, especially in commercial grain crops. However, the potential for producing fodder in these intercropping systems has received less attention.

The success of dairy operations depends on the availability of green fodder of better quality to animals and it is challenging to sustain the health and milk output of cattle without a supply of high-quality green fodder. The growing of fodder crops in a mixture with legumes has the potential to improve the palatability and digestibility of fodder (Kumar *et al* 2018, Kumar *et al.*, 2016) [7, 8]. It is a fact that the expense of feeding accounts for around 65-70% of the overall cost of raising cattle. To reduce the cost of feed and fodder supplies for sustainable livestock production, green fodder cultivation is an excellent option.

The nation is now dealing with a net shortfall of 44% concentrate feed components, 10.95% dry agricultural leftovers and 35.6% green fodder. By the year 2050, there will be a 13.2% shortfall in dry fodder and an 18.4% shortage in green fodder, based on the rate of expansion of forage resources (Anonymous, 2015) [2]. The most frequently grown crop in the world is maize (*Zea mays* L.), a domesticated cereal grain that originated in Central America. One of the most adaptable developing crops, it has a wide range of uses. Due to its maximum genetic production potential, maize is referred to as the "queen of cereals" internationally. The only food grain crop that may be cultivated in a variety of climates, ecosystems and environments is maize. Other varieties of maize include regular yellow/white grain, sweet corn, baby corn, popcorn, waxy corn, high-amylase corn, high-oil corn and quality protein maize, among others. In addition, maize is a significant industrial raw material that offers significant potential for value addition. The tall, annual C4 plant known as maize has opposite, broad, huge leaves that are carried alternately throughout the entire length of a sturdy stem. Its height ranges from 4 meters. The following are the botanical characteristics of various plant parts:

Root

Typically, maize plants possess three different types of roots: adventitious roots, which are fibrous roots that form from the lowermost nodes of the stem below ground and are the plant's active and effective roots, seminal roots, which emerge from the radical and remain for a long time and a brace or prop roots, which are produced by the lower two nodes. The roots spread outward and downward approximately equally quickly. Corn roots may grow to a maximum of 60 cm laterally and in-depth in suitable conditions.

Stem

Three to four centimeters are typically the maximum thickness of the stem. At the plant's base, its internodes are tiny and somewhat thick; as they ascend the stem, they get longer and thicker before beginning to taper once more. The ear-carrying internode has a longitudinal groove that enables the ear head (cob) to be positioned correctly. In maize, the higher leaves intercept more light and are a primary source of photosynthesis for the grain.

Flower

The female flowers (cobs or ears) develop at the top of condensed, lateral branches referred to as shanks that protrude from the leaf axils. The male flowers are inflorescences that finish in tassels, which are the apex of the stem. A loose panicle-like male (staminate) inflorescence produces sets of free spikelets, each of which is surrounded by a productive and sterile floret. Pairs of spikelets are produced by the female (pistillate) inflorescence, a spike, on the surface of a tightly packed rachis (central axis, or "cob"). The female flower can't easily be seen until the pale yellow silks emerge through the leaf whorl at the base of the ear because it is securely covered over by numerous layers of leaves and is thus enclosed by them to the stem. The act of cultivating more than one crop side by side on the same field is known as intercropping. The fundamental goal of intercropping aims to increase the output on a particular plot of land by using resources that a single crop would not otherwise be able to use effectively. Growing multiple crops concurrently in alternate rows of a single field is known as intercropping. (2013; Arif *et al.*, 2012 and Bilalis *et al.*, 2010) [1, 3]. It is a productive method for growing maize that not only reduces the space available for the growth of weeds but also boosts output per unit of land. Additionally, there are fewer odds of a crop being destroyed completely in the event of a serious disease or insect assault since the same disease or bug cannot attack two separate crops on the same field at the same time. Systems for intercropping legumes are important for the effective use of resources. Compared to single cropping, cereal-leaf intercropping proves to be a more efficient and lucrative cropping strategy (Evans *et al.*, 2001) [4]. Intercropping's primary goal is to increase overall production per unit of space and time while also making wise and equitable use of available resources, such as labour and land (Marer *et al.*, 2007) [10]. So in order to boosting the production of fodder maize via nourishing the fertility of soil this study was done with having following objectives.

1. To study the effect of different row ratio on growth parameters of fodder maize by intercropping maize with rajmash.
2. To workout indices for low input system/resources use efficiency.

Methodology

A field experiment entitled "Evaluation of Fodder Maize (*Zea mays* L.) and Rajmash (*Phaseolus vulgaris* L.) as Intercrop for Growth Parameters of Maize under Cold Arid Region of Ladakh'' was conducted during *Kharif*-2021 and *Kharif*-2022 at the experimental farm of High Mountain Altitude Arid Agriculture Research Institute, Leh, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir. The research was carried out in the High Mountain Altitude Arid Agriculture Research Institute's experimental farm in Leh, which is located at 34º10' N latitude, 77º42' E longitude and 3287 meters above sea level. The experiment's location was levelled and well-drained. From June 14 to September 14 there is a warm season with average high temperatures exceeding 31.12 °C in 2021 and 23.69 °C in 2022. The warmest month of the year in Leh was July, with average high temperatures of 35.5 °C in 2021 and 25.81 °C in 2022 and low temperatures of 9.25 °C. From November through March, the cold season lasts 5 months, with an average high temperature of 5.19 °C in 2021 and 5.44 °C in 2022. Leh saw its coldest months in January 2021 and December 2022, respectively, with average lows of -15.77 °C and -21.5 °C. Snow and rain totalled 29.1 mm in 2021 and 74.4 mm in 2022 for the yearly precipitation. Composite soil samples from the experimental plot were collected at a depth of 0 to 15 cm prior to the experiment and they underwent mechanical and chemical analysis. The findings of the samples obtained at the beginning of the experiment revealed that the soil had a neutral reaction, medium levels of accessible nitrogen and phosphorus and a high level of potassium.

Result

Plant height at 15 days interval (cm)

In Table 1, information on the effects of various intercropping crop configurations on maize plant height is provided.

In *Kharif*-2021, significantly maximum plant height at 15 DAS was recorded under T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practice)] as 20.36 cm which was found comparable to plant height of T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] as 20.34 cm followed by T6 [Maize + Rajmash intercropping (2:2) at 20 cm row spacing] with 19.54 cm. While the minimum plant height was recorded for T12 [Maize + Rajmash intercropping (6:4) at 20 cm row spacing] with 14.63 cm.

In *Kharif*-2022, maximum plant height at 15 DAS was recorded under T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] as 23.44 cm which was found comparable to plant height of T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practice)] as 21.65 cm followed by T4 [Maize + Rajmash intercropping (1:1) at 20 cm row spacing] with 21.10 cm and T6 [Maize + Rajmash intercropping (2:2) at 20 cm row spacing] with 21.07 cm. While the minimum plant height was recorded for T13 [Maize + Rajmash intercropping (6:6) at 20 cm row spacing] with 16.90 cm.

Maximum plant height at 30 DAS was recorded under T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] as 56.74 cm in *Kharif*-2021 and 59.62 cm in *Kharif*-2022 which was found comparable to plant height of T4 [Maize + Rajmash intercropping (1:1) at 20 cm row spacing] with 55.23 cm in *Kharif*-2021 and 57.54 cm in *Kharif*-2022. While the

minimum plant height was recorded for T13 [Maize + Rajmash intercropping (6:6) at 20 cm row spacing] with 37.43 cm in *Kharif*-2021 and 43.34 cm in *Kharif*-2022.

At 45 DAS, maximum plant height was observed for T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] with 114.29 cm and 118.26 cm in *Kharif*-2021 and *Kharif*-2022, respectively. Which was comparable to T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practice)] with 113.46 cm followed by T4 [Maize + Rajmash intercropping (1:1) at 20 cm row spacing] with 113.31 cm in *Kharif*-2021 and T4 [Maize + Rajmash intercropping (1:1) at 20 cm row spacing] as 116.14 cm followed by T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practice)] with 115.61 cm in *Kharif*-2022. The minimum plant height was recorded under T13 [Maize + Rajmash intercropping (6:6) at 20 cm row spacing] with 97.27 cm in *Kharif*-2021. However, the minimum plant height in *Kharif*-2022 was observed for T1 [Maize Line sowing (Sole crop) at 30 cm row spacing] with 101.55 cm.

Maximum plant height at 60 DAS was recorded under T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] as 186.38 cm in *Kharif*-2021 and 188.18 cm in *Kharif*-2022 which was found comparable to plant height of T4 [Maize + Rajmash intercropping (1:1) at 20 cm row spacing] with 182.15 cm in *Kharif*-2021 and 185.15 cm in *Kharif*-2022. Followed by, T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practice)] with 179.79 cm in *Kharif*-2021 and 181.19 cm in *Kharif*-2022. While the minimum plant height was recorded for T12 [Maize + Rajmash intercropping (6:4) at 20 cm row spacing] with 167.87 cm in *Kharif*-2021 and 170.12 cm in *Kharif*-2022.

At 75 DAS, maximum plant height in *Kharif*-2021 was observed for T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] with 267.28 cm followed by T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practice)] with 267.25 cm and T6 [Maize + Rajmash intercropping (2:2) at 20 cm row spacing] 265.61 cm. While, the minimum plant height was observed for T1 [Maize Line sowing (Sole crop) at 30 cm row spacing] with 247.29 cm. In *Kharif*-2022, maximum plant height was observed for T6 [Maize + Rajmash intercropping (2:2) at 20 cm row spacing] with 270.12 cm followed by T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] with 269.21 cm and T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practice)] with 269.18 cm. While, the minimum plant height was observed for T1 [Maize Line sowing (Sole crop) at 30 cm row spacing] and T4 [Maize + Rajmash intercropping (1:1) at 20 cm row spacing] with 251.11 cm.

In *Kharif*-2021, maximum plant height at 90 DAS was recorded under T4 [Maize + Rajmash intercropping (1:1) at 20 cm row spacing] with 307.29 cm, followed by T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] with 306.19 cm and T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practice)] with 303.68 cm. While, minimum plant height was recorded in T13 [Maize + Rajmash intercropping (6:6) at 20 cm row spacing] with plant height of 281.49 cm.

In *Kharif*-2022, maximum plant height at 90 DAS was recorded for T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] with 310.11 cm, followed by T4 [Maize + Rajmash intercropping (1:1) at 20 cm row spacing] with 309.17 cm and T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practice)] with 308.16 cm. While, minimum plant height was recorded in T13 [Maize + Rajmash intercropping (6:6) at 20 cm row spacing] with plant height of 284.17 cm which was comparable to T1 [Maize Line sowing (Sole crop) at 30 cm row spacing] with 284.19 cm.

Number of leaves per plant

Maize showed significant difference in number of leaves per plant recorded at 60 DAS as mentioned in table 2. The maximum number of leaves per plant was observed in T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] with 14.65 leaves per plant, followed by T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practice)] with 13.43 and T1 [Maize Line sowing (Sole crop) at 30 cm row spacing] with 13.19 leaves per plant in *Kharif*-2021. The lowest number of leaves per plant in *Kharif*-2021 was observed for T10 [Maize + Rajmash intercropping (4:4) at 20 cm row spacing] with 9.64 leaves per plant.

While in *Kharif*-2022, maximum number of leaves per plant was observed in T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] with 14.67 leaves per plant, followed by T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practice)] with 13.44 and T1 [Maize Line sowing (Sole crop) at 30 cm row spacing] with 13.22 leaves per plant. The lowest number of leaves per plant in *Kharif*-2021 was observed for T10 [Maize + Rajmash intercropping (4:4) at 20 cm row spacing] with 9.67 leaves per plant.

Leaf length (cm)

A significant difference was present in data recorded for leaf length at 60 DAS as mentioned in table 2. The maximum leaf length was observed in T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] with 94.11 cm in *Kharif*-2021 and 94.12 cm in *Kharif*-2022, followed by T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practice)] with 90.12 cm in *Kharif*-2021 and 90.11 cm in *Kharif*-2022 followed by, T8 [Maize + Rajmash intercropping (2:4) at 20 cm row spacing] with 86.15 cm in *Kharif*-2021 and 86.17 cm in *Kharif*-2022. The minimum leaf length in *Kharif*-2021 and in *Kharif*-2022 was observed for T10 [Maize + Rajmash intercropping (4:4) at 20 cm row spacing] with 50.74 cm and 50.76 cm, respectively.

Leaf width (cm)

The data regarding leaf width are presented in table 2. The maximum leaf width was observed in T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] with 8.92 cm in *Kharif*-2021 and 8.91 cm in *Kharif*-2022, followed by T1 [Maize Line sowing (Sole crop) at 30 cm row spacing] with 8.04 cm in *Kharif*-2021 and 8.06 cm in *Kharif*-2022 followed by, T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practice)] with 7.92 cm in *Kharif*-2021 and 7.91 cm in *Kharif*-2022. The minimum leaf width in *Kharif*-2021 and in *Kharif*-2022 was observed for T10 [Maize + Rajmash intercropping (4:4) at 20 cm row spacing] with 6.67 cm and 6.69 cm, respectively.

Discussion

Plant height at 15 days interval (cm): Plant height is a

crucial growth indicator to track the overall canopy architecture of the plant as well as the accumulation of dry matter by the plant. In general, maize plant height rose as the crop grew older and reached the harvest stage. The results showed that the height of the maize plants rose significantly from 30 to 75 days and then gradually up to the time of harvest.

Plant heights were significantly higher in the treatments T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing], T4 [Maize + Rajmash intercropping (1:1) at 20 cm row spacing] and T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practise)]. maybe as a result of decreased rivalry between maize plants and higher availability of nitrogen fixed by rajmash plants.

Minimum plant height was seen in all growth stages and both years in treatments T12 [Maize + Rajmash intercropping (6:4) at 20 cm row spacing] and T13 [Maize + Rajmash intercropping (6:6) at 20 cm row spacing], which shows that there was more competition between maize plants. This unfavourable interaction between fodder maize and legumes may have caused maize in intercropped treatments to grow less tall.

Number of leaves per plant, leaf length and leaf width

The primary photosynthetic organ of higher plants is the leaf. The leaf's wide, flat outside surface maximises light absorption per unit volume and reduces the distance that CO2 must travel from the leaf surface to the chloroplast. Crop plants' ability to photosynthesize is influenced by the size and quantity of their leaves (Kirankumar *et al.*, 2008) [6].

The results showed that the number of leaves per plant might be affected by the various treatments used in the experiment. T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] had the most leaves per plant, followed in both experimental years by T3 [Maize Line planting at 30 cm row spacing + Rajmash disseminated] and T1 [Maize Line sowing (Sole crop) at 30 cm row spacing]. While T10 [Maize + Rajmash intercropping (4:4) at 20 cm row spacing] was found to have the fewest leaves per plant in both years.

In general, it was noted that the intercropping arrangement also impacted the length of maize leaves. Following T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practise)], T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] and T8 [Maize + Rajmash intercropping (2:4) at 20 cm row spacing] in both years, the maximum leaf length was noted. In both *Kharif*s 2021 and 2022, T10 [Maize + Rajmash intercropping (4:4) at 20 cm row spacing] had the shortest leaf length.

T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] had the widest leaves, followed by T1 [Maize Line sowing (Sole crop) at 30 cm row spacing] and then T3 [Maize Line sowing at 30 cm row spacing + Rajmash broadcasted (Farmer's Practise)] in both *Kharif*-2021 and *Kharif*-2022. T10 [Maize + Rajmash intercropping (4:4) at 20 cm row spacing] had the smallest leaf width in *Kharif*s 2021 and 2022.

Legwaila *et al.* (2012) [9] and Hegde (1983) [5] both reported findings for leaf features that were similar.

Table 1: Plant height (cm) at 15 days interval of Maize plant as influenced by Maize and Rajmash intercropping

Treatments	Plant height 15 days		Plant height 30 days		Plant height 45 days		Plant height 60 days		Plant height 75 days		Plant height 90 days	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
T1	17.56	19.62	43.5	45.6	98.89	101.55	172.34	173.12	247.29	251.11	283.86	284.19
T2	-	-	-	-	-	-	-	-	-	-	-	-
T3	20.36	21.65	52.46	54.56	113.46	115.61	179.71	181.19	267.25	269.18	303.68	308.16
T4	17.87	21.1	55.23	57.54	113.31	116.14	182.15	185.15	249.52	251.11	307.29	309.17
T5	16.64	19.65	50.78	51.23	102.28	107.15	173.19	177.14	259.79	261.67	290.14	293.14
T6	19.54	21.07	47.62	51.67	97.77	111.17	177.92	179.21	265.61	270.12	295.13	301.31
T7	16.25	19.23	50.66	52.63	104.69	105.56	171.37	175.12	258.79	260.18	294.38	296.19
T8	18.76	20.63	49.16	53.32	105.26	108.06	173.58	176.23	260.44	262.11	294.37	297.19
T9	20.34	23.44	56.74	59.62	114.29	118.26	186.38	188.18	267.28	269.21	306.19	310.11
T10	15.19	18.11	47.34	49.55	104.37	106.16	170.39	173.17	258.83	259.18	286.86	289.17
T11	17.74	19.7	52.38	55.65	108.39	110.18	176.72	181.18	263.18	267.18	300.58	302.13
T12	14.63	17.1	42.39	48.57	103.72	106.56	167.87	170.12	254.75	259.19	287.39	290.15
T13	15.9	16.9	37.43	43.34	97.27	103.17	168.36	170.19	258.68	261.06	281.49	284.17
S.E(m)±	0.436	0.492	0.563	0.581	2.967	3.105	5.621	5.891	7.221	7.672	9.366	9.634
CD (p<0.05)	3.056	3.862	4.621	4.734	8.621	9.041	17.15	18.11	22.25	23.72	28.11	29.23

Table 2: Plant stand (%), No. of Leaves/plant, Leaf Length (cm) and Leaf Width (cm) of Maize plant as influenced by Maize and Rajmash intercropping

Treatments	Plant stand (%)		No. of Leaves / Plant		Leaf Length (cm)		Leaf Width (cm)	
Maize	2021	2022	2021	2022	2021	2022	2021	2022
T1	90	91	13.19	13.22	81.61	81.62	8.04	8.06
T2	-	-	-	-	-	-	-	-
T3	87	90	13.43	13.44	90.12	90.11	7.92	7.91
T4	92	94	10.15	10.17	53.14	53.17	6.72	6.74
T5	91	93	10.84	10.85	58.45	58.47	6.86	6.88
T6	91	92	11.03	11.05	61.12	61.11	6.92	6.91
T7	88	90	12.05	12.07	75.42	75.43	7.65	7.66
T8	90	91	12.66	12.67	86.15	86.17	7.7	7.8
T9	91	92	14.65	14.67	94.11	94.12	8.92	8.91
T10	91	92	9.64	9.67	50.74	50.76	6.67	6.69

T11	92	94	12.16	12.18	82.12	82.14	7.7	7.71
T12	91	93	11.54	11.56	66.43	66.45	7.5	7.51
T13	90	91	11.96	11.98	72.64	72.65	7.54	7.56
S.E(m)±	2.031	2.432	0.541	0.632	1.542	1.656	1.045	1.234
CD (p<0.05)	7.830	8.142	2.564	2.675	4.965	5.112	3.675	3.878

Conclusion

The results show that T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] had higher growth parameters and yield-attributing characters than T8 [Maize only and reaching different phonological stages]; consequently, T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] had higher yields for both crops.T9 [Maize + Rajmash intercropping (2:6) at 20 cm row spacing] was discovered to be the superior to give highest values among intercropping studies as well as quality parameters, gross return, net return and B-C ratio. This was taken into account when considering land equivalent ratio, relative crowding coefficient, production efficiency, aggressivity, quality of fodder and economics under different treatments.

Hence, Maize + Rajmash intercropping in 2:6 ratio at 20 cm row spacing is recommended to farmers of Ladakh region as it is highly economic and sustainable than pure cultivation of maize.

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