



Research article

Productivity of fodder ryegrass and chinese cabbage intercropping as influenced by nutrient management

Brijesh Kumar¹, Magan Singh^{1*}, Deepak Kumar¹, B. L. Meena², Sandeep Kumar¹, Rekha Rana⁴, Ajay Kumar³ and Avaneesh Kumar¹

¹ICAR-National Dairy Research Institute, Karnal-132001, India

²ICAR-Central Soil Salinity Research Institute, Karnal-132001, India

³Banaras Hindu University, Varanasi-221005, India

⁴Hemvati Nandan Bahuguna Garhwal University, Srinagar-246174, India

*Corresponding author email: magansingh07@gmail.com

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Abstract

The experiment was carried out during the winter season of 2021 and 2022 at the Research Block of Agronomy Section, ICAR-National Dairy Research Institute, Karnal, Haryana (India). Suitable integrated nutrient management practice for ryegrass and Chinese cabbage intercropping was worked out for higher fodder yield and crop growth in the sub-tropical zone having a semi-arid climate. The experiment was conducted in Factorial (RBD) consisting of four planting ratios (RG- sole ryegrass, CC- chinese cabbage, 1RG:1CC- ryegrass + chinese cabbage, 2RG:1CC- ryegrass + chinese cabbage and four nutrient management treatments (NM₁-absolute control, NM₂-100% RDF, NM₃-75% RDF + 25% N through FYM, NM₄-75% RDF + 25% N through FYM + PGPR). The highest dry matter accumulation (DMA), crop growth rate (CGR), relative growth rate (RGR), green fodder yield (GFY), and dry fodder yield (DFY) of intercropped with ryegrass and Chinese cabbage were observed when they were grown as sole crops. In the case of nutrient management, growth attributes, GFY, and DFY of intercropped ryegrass and Chinese cabbage were significantly higher with the crop fertilized with NM₄- (75% RDF + 25% N through FYM + PGPR) treatment. The intercropping of ryegrass and Chinese cabbage performed better with integrated nutrient management than other treatments.

Keywords: Chinese cabbage, Crop growth, Intercropping, Nutrient management, Productivity, Ryegrass

Introduction

Annual ryegrass (*Lolium multiflorum*) is a popular cool-season forage crop grown globally in annual and perennial forms. It is widely cultivated in North and South America, Europe, New Zealand, and Australia (Singh *et al.*, 2021). The grass offers numerous advantages, such as high yield potential, quick establishment, and adaptability to heavy and waterlogged soils (Rana *et al.*, 2013). The seeding density is a critical factor in determining the flexibility and productivity of ryegrass cultivars. Too high plant populations of ryegrass can result in lower yields (Jan *et al.*, 2000) and an increased proportion of sterile plants, making them more susceptible to diseases than the standard population (Robert and Singh, 1981). Additionally, providing high-quality diets with readily available carbohydrates improves ruminant tolerance to nitrate (Ramteke *et al.*, 2019). In India, *Brassica compestris*

var. chinensis cabbage, also known as Toria, is cultivated as a fodder crop. These crops serve as livestock feed with their green leaves and stems. The success of rapeseed-mustard plants largely depends on their density per unit area of soil. Optimal plant distribution results in efficient nutrient and moisture utilization, weed suppression, and ultimately higher yields (Sonani *et al.*, 2002).

The objective of this study is to evaluate the effect of various nutrient management practices-such as organic, inorganic, and integrated approaches, on the growth and yield performance of fodder ryegrass and Chinese cabbage grown in an intercropping system. Intercropping is a farming technique designed to enhance overall productivity per unit area and time while optimizing land resources and inputs (Marer *et al.*, 2019). The excessive use of chemical fertilizers in intensive cropping systems has led to nutrient imbalances in the soil, which

adversely affect soil health and crop yields. To achieve sustainable yields, a suitable combination of organic manure and chemical fertilizers must be applied (Yadav *et al.*, 2022). Farmyard manure (FYM) is a valuable source of macro and micronutrients for enhancing crop yield (Kumar *et al.*, 2021). Proper application methods, incorporation timing, and manure decomposition by soil microorganisms increase nutrient availability for crops (Aulakh *et al.*, 2022). Plant growth-promoting bacteria (PGPR) play a significant role in enhancing plant growth by solubilizing nutrients, producing hormones, fixing nitrogen, and improving water and nutrient absorption (Yadav *et al.*, 2022). They also stimulate root development and increase enzymatic activity, while promoting beneficial microorganisms to further enhance plant growth and suppress pathogens. Integrated nutrient management (INM) is an environmentally friendly and cost-effective farming approach that combines traditional and modern nutrient management practices. It involves utilizing various sources of nutrition, such as organic, inorganic, and biological fertilizers, synergistically to achieve optimal results (Wu and Ma, 2015; Kumar *et al.*, 2022b). Considering these facts, Intercropping of ryegrass with Chinese cabbage and adoption of integrated nutrient management, incorporating farmyard manure, appropriate fertilizer levels, biofertilizers, and PGPR, is essential to improve crop production, productivity, profitability, and efficient nutrient utilization in fodder production (Kaur *et al.*, 2023).

Materials and Methods

Location of experiment and climatic conditions: The experiment was carried out during the winter seasons of 2021 and 2022 at the Research Block of Agronomy Section, ICAR–National Dairy Research Institute, Karnal, Haryana (India). Karnal is located in the northwestern

zone of Haryana state at 245 meters above mean sea level, 29°43' latitude and 76°58' longitude in the sub-tropical zone. The climate of the experimental site was semi-arid, characterized by hot and dry summers and severe cold during the winter season. The average maximum temperature was 33.5 to 33.6°C, the minimum temperature was near 12.6 to 14.9°C, the relative humidity was maximum 100%, the minimum relative humidity was 30.3 to 40%, total rainfall was 39.2 mm both years, the average evaporation during both years was 1.8 to 2.1 mm during the crop growth period accompanied by frost in the peak winter months of December and January. The annual rainfall of the area varies from 690 to 720 mm with a bimodal distribution, over 70% of which occurs during the main rainy season (July to September) and 30% during the rest of the months, especially during February to April (Fig 1-2). The soil of the experimental field was well-drained clay loam soil. The soil has (15 cm top soil) pH 7.8, soil organic carbon 0.65%, available nitrogen 192.92 kg ha⁻¹, available phosphorus 24.23 kg ha⁻¹ and available potassium 203.43 kg ha⁻¹.

Experiment treatment details: The experiment was carried out in FRBD, consisting of four planting ratios (RG-sole ryegrass, CC-chinese cabbage, 1RG:1CC-ryegrass + chinese cabbage, 2RG:1CC-ryegrass + chinese cabbage) and four nutrient management treatments (NM₁-absolute control, NM₂-100% RDF, NM₃-75% RDF + 25% N through FYM, NM₄-75% RDF + 25% N FYM + PGPR).

Crop management practices: The experimental field was prepared using a disc harrow and a single pass of a rotavator, followed by leveling. On 15th October 2021 and 12th October 2022, the fodder ryegrass var - Makkhan grass and mustard var.- *chinensis* cabbage were sown, respectively, using a seed rate of 10 kg ha⁻¹ for ryegrass and 5 kg ha⁻¹ for Chinese cabbage. In intercropping

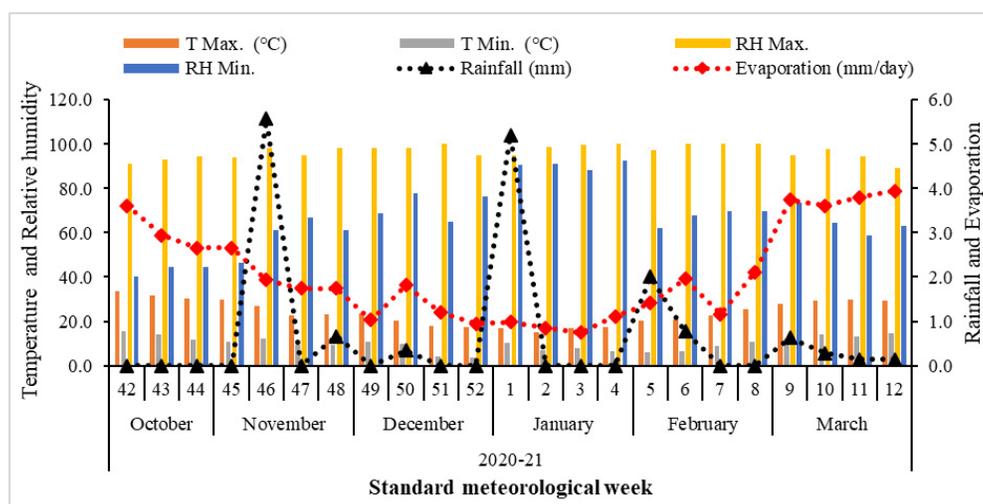


Fig 1. Mean weekly meteorological data for ryegrass and chinese cabbage during 2020-21

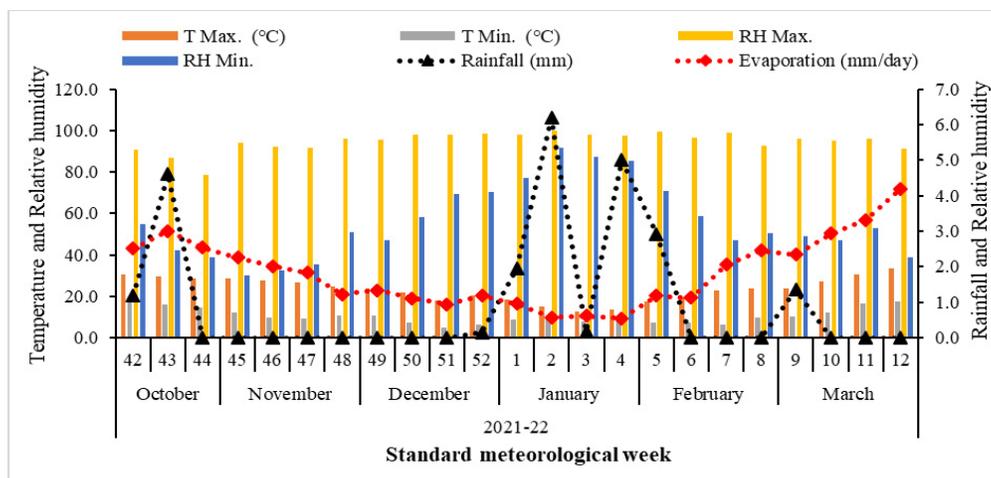


Fig 2. Mean weekly meteorological data for ryegrass and Chinese cabbage during 2022-21

treatments, the arrangement of the Chinese cabbage component was determined using a replacement series. In 1RG:1CC treatment, one row of Chinese cabbage was alternated after every row of ryegrass, while in 2RG:1CC treatment, a single row of Chinese cabbage was planted after every two rows of ryegrass. The row-to-row spacing for both crops was maintained at 30 cm. Before sowing, pre-sowing irrigation was applied to provide sufficient moisture for germination and establishment of both crops in both years. Fodder ryegrass and Chinese cabbage were harvested manually from the field at 40 DAS and further, two more cuttings were taken at 30-day intervals.

Statistical analysis: Experimental data were analyzed in Microsoft Excel and R software with the help of the analysis of variance (ANOVA) technique, where 'F-test' was used for evaluating the significance of the difference at a 0.05 probability level in a factorial randomized block design (FRBD). Statistical significance among treatments means differences for various parameters were analyzed by critical difference (CD) at a 0.05 probability level. For pooled analysis of the two experimental years, the 'F-test' was used to test the homogeneity of error variance (Gomez and Gomez, 1984). Accordingly, a pooled analysis of recorded data was done.

Results and Discussion

Growth parameters

Plant height: The planting ratios and nutrient management had a significant impact on the plant height of ryegrass and Chinese cabbage (Table 1). However, the plant height of both ryegrass and Chinese cabbage remained relatively consistent throughout the study years. However, there was no significant difference in plant height at 30 days after sowing (DAS) for both

ryegrass and Chinese cabbage. Specifically, at the 1st cut plant height (65.64 cm) of sole ryegrass was significantly higher. Ryegrass with a planting ratio of 1RG:1CC recorded maximum plant height at the 2nd and 3rd cuts (70.20 and 70.93 cm, respectively) and was statistically similar to the 2RG:1CC planting ratio (68.03 and 69.39 cm, respectively).

However, optimizing the planting ratio in the intercropping system can reduce competition for nutrients, water, light, space, and air circulation, which ultimately promotes the shoot growth of the crop (Dunea et al., 2014; Koireng et al., 2022). Among the different nutrient management options, the treatment NM_4 - (75% RDF + 25% N through FYM + PGPR) resulted in significantly higher plant height at each cut of ryegrass (68.91 cm, 74.30 cm, and 74.67 cm, respectively). Chinese cabbage showed significantly higher plant height (147.47 cm) with a planting ratio of 1RG:1CC and was statistically similar to the 2RG:1CC planting ratio (143.18 cm). Among the different nutrient management options, the treatment NM_4 - (75% RDF + 25% N through FYM + PGPR) resulted in significantly higher plant height (157.63 cm) at the harvesting of Chinese cabbage. Organic sources of nutrients in INM, such as manures, release nutrients gradually, providing sustained nutrient availability throughout the growing season and PGPR solubilize and mobilize essential nutrients, making them more accessible to mustard, oats-chickpea and oats-berseem. These findings were supported by previous studies (Bisht et al., 2018; Koireng et al., 2022; Kushwah et al., 2024).

Leaf length: Different planting ratios and nutrient management caused significant changes in the leaf length of ryegrass and Chinese cabbage (Table 2). However, the leaf length of ryegrass and Chinese cabbage remained similar in the study years. No significant difference was found in leaf length at 30 DAS of ryegrass and Chinese

Table 1. Effect of planting ratios and nutrient management on the plant height of ryegrass and chinese cabbage (pooled data)

Treatments	Plant height (cm)					
	Ryegrass				Chinese cabbage	
Year	30 DAS	1 st Cut	2 nd Cut	3 rd Cut	30 DAS	At harvest
2020-21	25.82 ^a	62.13 ^a	67.66 ^a	67.99 ^a	33.39 ^a	143.47 ^a
2021-22	26.28 ^a	63.39 ^a	68.17 ^a	68.01 ^a	33.80 ^a	144.82 ^a
SEM	0.46	0.90	0.73	0.79	0.45	1.28
LSD (P<0.05)	NS	NS	NS	NS	NS	NS
Planting ratios						
RG	26.75 ^a	65.64 ^a	65.91 ^b	66.08 ^b	-	-
CC	-	-	-	-	33.48 ^a	140.80 ^b
1RG:1CC	25.47 ^a	60.48 ^b	70.20 ^a	70.93 ^a	33.58 ^a	147.47 ^a
2RG:1CC	25.93 ^a	62.16 ^b	68.03 ^{ab}	69.39 ^{ab}	33.72 ^a	143.18 ^{ab}
SEM	0.57	1.11	0.89	0.96	0.55	1.57
LSD (P<0.05)	NS	3.15	2.55	2.74	NS	4.47
Nutrient management						
NM1	25.02 ^a	53.50 ^c	58.17 ^c	57.31 ^c	32.73 ^a	126.69 ^d
NM2	26.10 ^a	64.91 ^b	70.65 ^b	71.74 ^b	34.44 ^a	150.41 ^b
NM3	26.18 ^a	63.73 ^b	68.54 ^b	68.28 ^b	33.72 ^a	141.86 ^c
NM4	26.90 ^a	68.91 ^a	74.30 ^a	74.67 ^a	33.47 ^a	157.63 ^a
SEM	0.66	1.28	1.03	1.11	0.63	1.81
LSD (P<0.05)	NS	3.63	2.94	3.17	NS	5.17

RG: Ryegrass sole; CC: Chinese cabbage; 1RG:1CC: Ryegrass + Chinese cabbage; 2RG:1CC: Ryegrass + Chinese cabbage; NM₁: Control (absolute); NM₂: 100% RDF; NM₃: 75% RDF + 25% N through FYM; NM₄: 75% RDF + 25% N through FYM + PGPR

cabbage. Among the planting ratios, significantly higher leaf lengths were recorded at 1st cut with sole ryegrass (23.76 cm), at 2nd and 3rd cuts of ryegrass with 1RG:1CC (28.19 cm and 29.86 cm), which were statistically at par with 2RG:1CC (27.70 and 28.32 cm) planting ratios. In nutrient management, the maximum leaf length (26.36, 31.29, and 33.19 cm, respectively) of ryegrass was obtained from the crop fertilized with NM₄ (75% RDF + 25% N FYM + PGPR) treatment as compared to other nutrient management options. The leaf length of Chinese cabbage was recorded significantly higher with planting ratios 1RG:1CC (44.57 cm) and statistically on par with 2RG:1CC (43.21 cm). Concerning the effect of nutrient management on the Chinese cabbage maximum leaf length (48.20 cm) was found with the application of NM₄-(75% RDF + 25% N through FYM + PGPR) treatment. INM strategies involve the use of biofertilizers that help to fix atmospheric nitrogen and solubilize nutrients in the soil. Improved nutrient availability from biofertilizers positively impacts leaf length of oat-lathyrus (Biswas *et al.*, 2020; Dutta *et al.*, 2023).

Number of leaves per plant: The number of leaves per plant of ryegrass and Chinese cabbage remained similar between the study years. A Significant difference was found between planting ratios and nutrient management options (Table 3). A significantly higher number of leaves per plant of ryegrass was recorded at 1st cut in sole ryegrass (9.87), whereas 2nd and 3rd cuts were higher with the ratio of 1RG:1CC (10.80 and 11.21) and statistically at par with 2RG:1CC. In nutrient management, the maximum number of leaves per plant was recorded with NM₄-(75% RDF + 25% N through FYM + PGPR) treatment at each cut of ryegrass (10.40, 11.57 and 12.05) as compared to the rest of the other treatments. Likewise, the significantly higher number of leaves per plant of Chinese cabbage was recorded with the 1RG:1CC (14.67) and statistically on par with the 2RG:1CC (14.33) planting ratio. Among nutrient management, the highest number of leaves per plant (15.86) of Chinese cabbage was obtained with NM₄-(75% RDF + 25% N through FYM + PGPR) treatment at harvest. The rise in the number of leaves per plant resulted from the utilization of the NM₄-(75% RDF + 25% N through

Table 2. Effect of planting ratios and nutrient management on the leaf length of ryegrass and chinese cabbage (pooled data)

Treatments	Leaf length (cm)					
	Ryegrass				Chinese cabbage	
Year	30 DAS	1 st Cut	2 nd Cut	3 rd Cut	30 DAS	At harvest
2020-21	17.17 ^a	22.18 ^a	27.15 ^a	28.87 ^a	22.39 ^a	43.30 ^a
2021-22	17.59 ^a	22.86 ^a	27.58 ^a	29.41 ^a	23.47 ^a	44.10 ^a
SEM	0.32	0.37	0.48	0.56	0.52	0.44
LSD (P<0.05)	NS	NS	NS	NS	NS	NS
Planting ratios						
RG	16.97 ^a	23.76 ^a	26.20 ^b	27.25 ^b	-	-
CC	-	-	-	-	22.58 ^a	42.58 ^b
1RG:1CC	17.63 ^a	21.39 ^b	28.19 ^a	29.86 ^a	23.17 ^a	44.57 ^a
2RG:1CC	17.53 ^a	22.40 ^b	27.70 ^{ab}	28.32 ^{ab}	23.04 ^a	43.21 ^{ab}
SEM	0.39	0.46	0.59	0.69	0.63	0.53
LSD (P<0.05)	NS	1.30	1.71	2.00	NS	1.52
Nutrient management						
NM1	16.41 ^a	16.41 ^c	21.33 ^c	23.96 ^c	21.94 ^a	36.55 ^c
NM2	18.05 ^a	24.23 ^b	29.21 ^{ab}	30.68 ^{ab}	23.57 ^a	45.70 ^b
NM3	17.43 ^a	23.08 ^b	27.62 ^b	28.74 ^b	23.06 ^a	44.36 ^b
NM4	17.62 ^a	26.36 ^a	31.29 ^a	33.19 ^a	23.15 ^a	48.20 ^a
SEM	0.45	0.53	0.68	0.79	0.73	0.62
LSD (P<0.05)	NS	1.50	2.56	2.98	NS	2.32

RG: Ryegrass sole; CC: Chinese cabbage; 1RG:1CC: Ryegrass + Chinese cabbage; 2RG:1CC: Ryegrass + Chinese cabbage; NM₁: Control (absolute); NM₂: 100% RDF; NM₃: 75% RDF + 25% N through FYM; NM₄: 75% RDF + 25% N through FYM + PGPR

FYM + PGPR) treatment. Organic fertilizer (FYM and PGPR) and inorganic fertilizer mutually enhance the availability of nutrients in the soil, making them more accessible to plant roots, which can positively impact leaf growth (Kumar *et al.*, 2022a; Kumar *et al.*, 2023). The better leaf growth observed with the application of FYM improves plant growth and progression in the mustard and oats crops, as highlighted by Singh and Sinsinwar (2006); Kumar *et al.* (2022b).

Dry matter accumulation: The results indicated that the planting ratios and nutrient management had a significant effect on the dry matter accumulation of ryegrass and Chinese cabbage and a non-significant effect between the study years (Fig. 3). The maximum dry matter accumulation was recorded in sole ryegrass at 0-60 DAS, 60-90 DAS, and 90-120 DAS (228.88, 238.43 and 254 gm⁻², respectively) of ryegrass as compared to the rest of the other planting ratios. In the case of nutrient management, significantly higher dry matter accumulation at 0-60 DAS, 60-90 DAS, and 90-120 DAS (152.18, 165.81, and 175.79 g m⁻²) was recorded with the imposing NM₄-(75% RDF + 25% N through FYM + PGPR)

treatment at the growth period of ryegrass. Similarly, maximum dry matter accumulation was recorded with the sole Chinese cabbage (621.52 gm⁻²) at 30-60 DAS. Among nutrient management, maximum dry matter accumulation at 30-60 DAS (368.38 gm⁻²) was recorded with the NM₄-(75% RDF + 25% N through FYM + PGPR) treatment at the harvest of Chinese cabbage. Utilizing a combination of NM₄ (75% RDF + 25% N through FYM + PGPR) and sole stands of crops has demonstrated optimal outcomes for enhancing the growth characteristics of both ryegrass and Chinese cabbage plants. The most effective approach for cultivating ryegrass involves sole stands in the intercropping method alongside chinese cabbage, resulting in the greatest growth potential for the ryegrass (Yang *et al.*, 2018; Biswas *et al.*, 2020).

Crop growth rate (CGR): Crop growth rate was significantly higher recorded with the sole stands of ryegrass at 0-60 DAS, 60-90 DAS, and 90-120 DAS (3.81, 7.96, and 8.47 g m⁻² day⁻¹, respectively) of ryegrass (Fig. 4). In the case of nutrient management, the CGR of ryegrass was significantly higher recorded with crop was fertilized with NM₄ (75% RDF + 25% N through FYM + PGPR)

Fodder ryegrass and chinese cabbage intercropping

Table 3. Effect of planting ratios and nutrient management on the number of leaves per plant of ryegrass and Chinese cabbage (pooled data)

Treatments	Number of leaves per plant					
	Ryegrass				Chinese cabbage	
Year	30 DAS	1 st Cut	2 nd Cut	3 rd Cut	30 DAS	At harvest
2020-21	3.65 ^a	9.35 ^a	10.54 ^a	10.97 ^a	4.90 ^a	14.36 ^a
2021-22	3.74 ^a	9.52 ^a	10.64 ^a	11.10 ^a	5.03 ^a	14.62 ^a
SEM	0.07	0.09	0.12	0.14	0.09	0.15
LSD (P<0.05)	NS	NS	NS	NS	NS	NS
Planting ratios						
RG	3.61 ^a	9.87 ^a	10.30 ^a	10.81 ^a	-	-
CC	-	-	-	-	4.85 ^a	14.07 ^b
1RG:1CC	3.75 ^a	9.10 ^b	10.80 ^a	11.21 ^a	5.04 ^a	14.67 ^a
2RG:1CC	3.73 ^a	9.35 ^b	10.67 ^a	11.08 ^a	5.01 ^a	14.33 ^{ab}
SEM	0.08	0.11	0.15	0.17	0.11	0.18
LSD (P<0.05)	NS	0.32	NS	NS	NS	0.51
Nutrient management						
NM1	3.49 ^a	7.91 ^c	9.08 ^c	9.74 ^c	4.69 ^a	13.20 ^c
NM2	3.84 ^a	9.87 ^b	11.05 ^b	11.42 ^b	5.16 ^a	14.67 ^b
NM3	3.71 ^a	9.58 ^b	10.65 ^b	10.94 ^b	4.98 ^a	14.23 ^b
NM4	3.75 ^a	10.40 ^a	11.57 ^a	12.05 ^a	5.03 ^a	15.86 ^a
SEM	0.10	0.13	0.17	0.20	0.12	0.21
LSD (P<0.05)	NS	0.37	0.49	0.56	NS	0.78

RG: Ryegrass sole; CC: Chinese cabbage; 1RG:1CC: Ryegrass + Chinese cabbage; 2RG:1CC: Ryegrass + Chinese cabbage; NM₁: Control (absolute); NM₂: 100% RDF; NM₃: 75% RDF + 25% N through FYM; NM₄: 75% RDF + 25% N through FYM + PGPR

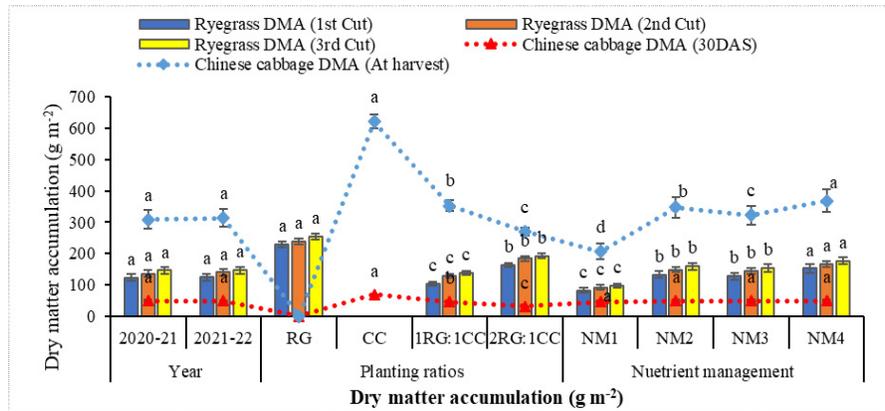


Fig 3. Effect of planting ratios and nutrient management on dry matter accumulation (DMA) of ryegrass and Chinese cabbage

treatment at 0-60 DAS, 60-90 DAS, and 90-120 DAS (2.54, 5.53 and 5.86 g m⁻² day⁻¹), respectively. Similarly, maximum CGR had been recorded with sole stands of Chinese cabbage at 0-30 DAS and 30-60 DAS (2.30 and 18.42g m⁻² day⁻¹). Under the nutrient management options, significantly higher CGR at 30-60 DAS (11.05

g m⁻² day⁻¹) of Chinese cabbage was obtained with imposing NM₄-(75% RDF + 25% N through FYM + PGPR) treatment. INM practices lead to enhanced crop growth of mustard and maize-wheat, and sorghum-guar crops (Kumar *et al.*, 2015; Biswas *et al.*, 2020; Bhakar *et al.*, 2021).

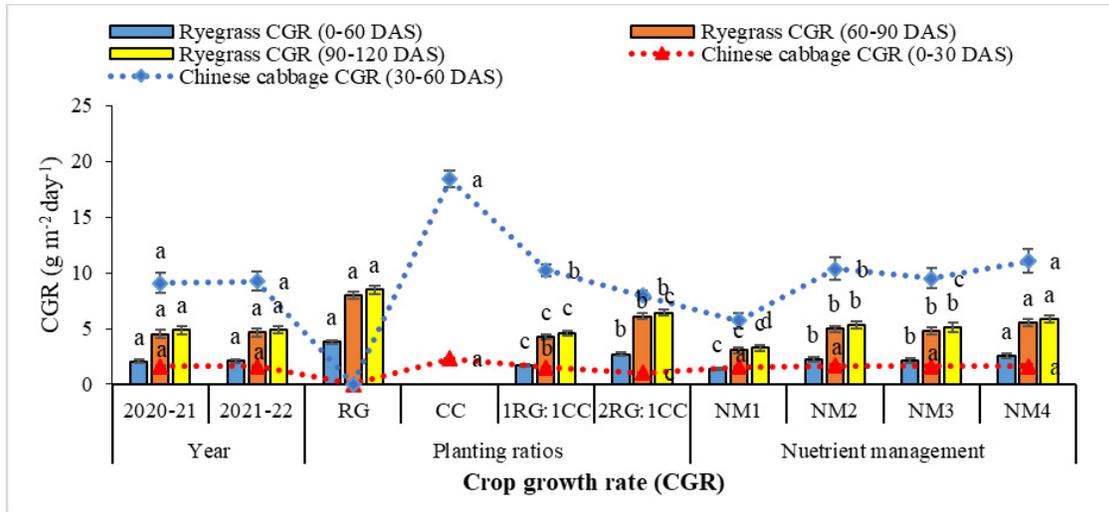


Fig 4. Effect of planting ratios and nutrient management on crop growth rate (CGR) of ryegrass and Chinese cabbage

Relative growth rate (RGR): Results revealed that different planting ratios and nutrient management options cause significant changes in the RGR of ryegrass and Chinese cabbage (Fig. 5). However, the RGR of ryegrass and Chinese cabbage remained similar in the study years. The results of the relative growth rate varied significantly higher with sole stands of ryegrass at 0-60 DAS, 60-90 DAS, and 90-120 DAS (90.08, 181.93, and 183.73 mg g⁻¹ day⁻¹, respectively). In the case of nutrient management, the CGR of ryegrass was recorded significantly higher with crop fertilized with NM₄-(75% RDF + 25% N through FYM + PGPR) treatment at 0-60 DAS, 60-90 DAS, and 90-120 DAS (65.71, 134.22 and 135.74 mg g⁻¹ day⁻¹). Results revealed that maximum RGR was recorded with sole Chinese cabbage (71 mg g⁻¹ day⁻¹) at 30-60 DAS of Chinese cabbage. Among nutrient management, maximum RGR (54.80 mg g⁻¹ day⁻¹) was

recorded with the NM₄-(75% RDF + 25% N through FYM + PGPR) treatment at 30-60 DAS of Chinese cabbage. Similar types of findings were observed earlier (Verdelli et al. 2012; Biswas et al., 2020).

Fodder yield

Green fodder yield (GFY) and dry fodder yield (DFY): Based on the information, the study found that the study years did not have a significant impact on green fodder yield. However, planting ratios and nutrient management options were found to significantly affect green and dry fodder yield (Table 4). Among the different planting ratios, the 2RG:1CC planting ratio resulted in significantly higher total GFY and DFY (654.76 and 80.87 q ha⁻¹) compared to other planting ratios. By carefully selecting the planting ratio, positive interactions can

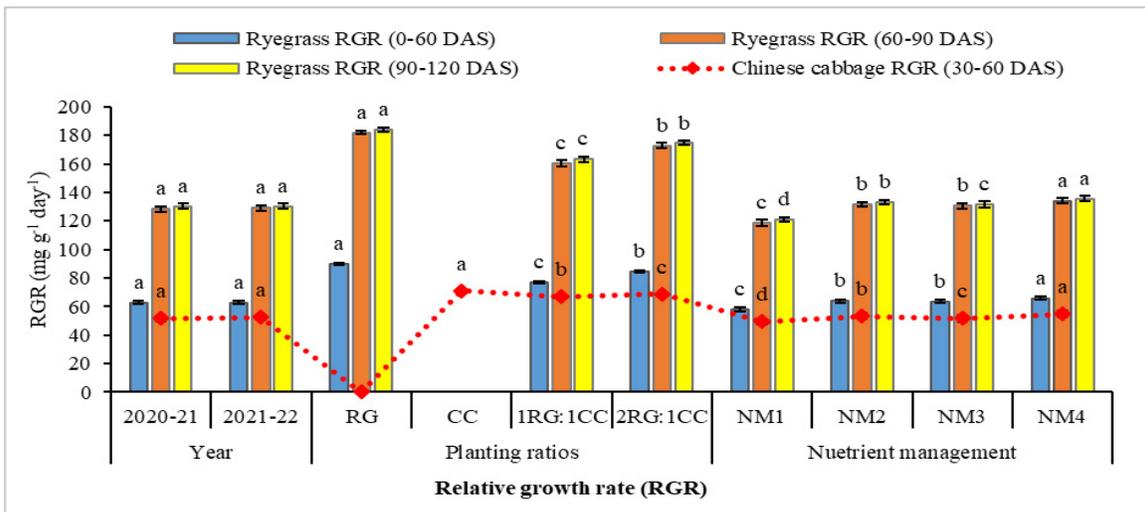


Fig 5. Effect of planting ratios and nutrient management on relative growth rate (RGR) of ryegrass and Chinese cabbage (pooled data)

Fodder ryegrass and chinese cabbage intercropping

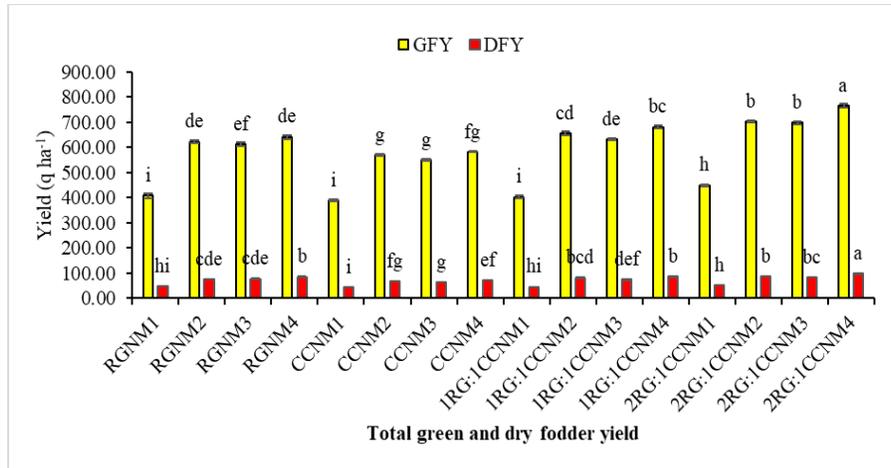


Fig 6. Interaction effect of planting ratios and nutrient management on Total green and dry fodder yield of ryegrass and chinese cabbage

Table 4. Effect of planting ratios and nutrient management on green and dry fodder yield ryegrass and chinese cabbage (pooled data)

Treatments	Ryegrass + Chinese cabbage	
	Green fodder yield	Dry fodder yield
Year	Total	Total
2020-21	582.55 ^a	71.26 ^a
2021-22	588.32 ^a	72.46 ^a
SEM	2.48	0.51
LSD (P<0.05)	NS	NS
Planting ratios		
RG	571.32 ^c	72.18 ^b
CC	523.01 ^d	62.15 ^c
1RG:1CC	592.64 ^b	72.22 ^b
2RG:1CC	654.76 ^a	80.87 ^a
SEM	3.51	0.71
LSD (P<0.05)	9.93	2.02
Nutrient management		
NM1	412.66 ^d	47.75 ^d
NM2	637.96 ^b	78.76 ^b
NM3	623.10 ^c	74.70 ^c
NM4	668.01 ^a	86.22 ^a
SEM	3.51	0.71
LSD (P<0.05)	9.93	2.02

RG: Ryegrass sole; CC: Chinese cabbage; 1RG:1CC: Ryegrass + Chinese cabbage; 2RG:1CC: Ryegrass + Chinese cabbage; NM₁: Control (absolute); NM₂: 100% RDF; NM₃: 75% RDF + 25% N through FYM; NM₄: 75% RDF + 25% N through FYM + PGPR

be promoted while minimizing competition, thereby improving green fodder production. Previous studies have highlighted the importance of appropriate planting ratios in achieving these outcomes (Kumar *et al.*, 2014). In the case of nutrient management highest total GFY and DFY (668.01 and 86.22 q ha⁻¹) for the intercropped ryegrass and Chinese cabbage were obtained with NM₄- (75% RDF + 25% N through FYM + PGPR) treatment. The interaction effect of planting ratios and nutrient management was found to be significantly positive for the total green and dry fodder yield of ryegrass and Chinese cabbage. On the other hand, the interaction effect shows that the 2RG:1CCNM₄ treatment combination had the highest GFY and DFY (766.75 and 99.36 q ha⁻¹). The lowest total GFY and DFY (389.66 and 43.97 q ha⁻¹) were recorded with the CCNM₁ treatment combination (Fig 6). Integrated nutrient management practices, which combine organic and inorganic fertilizers, have a positive impact on GFY and DFY due to the synergistic effect of different nutrient sources. This approach optimizes the nutrient composition of the soil, ensuring that plants have access to a wide range of necessary elements. It improves soil fertility, balances nutrient supply, recycles nutrients, enhances soil health, and promotes sustainable crop yields (Biswas *et al.*, 2020). The presence of PGPR in the root zone promotes nutrient acquisition and utilization by plants, ultimately increasing the productivity of green and dry fodder (Ponmozhi *et al.*, 2019; Kumar *et al.*, 2022c; Mubeena *et al.*, 2024).

Conclusion

Based on the findings, it was concluded that intercropping of ryegrass and Chinese cabbage with integrated nutrient management resulted in higher plant height, number of leaves per plant, and leaf length of intercropped ryegrass and Chinese cabbage at the 1st cut; significantly higher values were recorded with sole stands. At the 2nd and 3rd

cuts with planting ratio 1RG:1CC and NM₄-(75% RDF + 25% N through FYM + PGPR) treatment was significantly higher in plant height, number of leaves per plant, leaf length of intercropped ryegrass and chinese cabbage and statistically similar to 2RG:1CC planting ratio and NM₄-(75% RDF + 25% N through FYM + PGPR) treatment. DMA, CGR, RGR, GFY, and DFY of intercropped ryegrass and Chinese cabbage were significantly higher with sole stand crops, while fertilized with NM₄-(75% RDF + 25% N through FYM + PGPR) treatment. Overall, higher green and dry fodder yield was achieved with the intercropping of 2RG:1CC planting ratio of row with the application of 75% RDF + 25% N through FYM + PGPR-(NM₄) treatment.

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