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Small Millets with Legumes Intercropping for Climate Smart Agriculture

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Abstract

A specific combination of early leaf area development, maximum solar energy fascination, conditions favouring efficient translocation of dry matter to the seed, root nodules fixing more nitrogen in the soil, and finally crop canopy efficiency will be more during the growing season, as demonstrated by finger millet with black gram at different plant densities and row spacing. Millet-pulse intercropping system provides double economy with such minimal inputs crops where the former requires less input and the later will increase soil fertility and health by biological nitrogen fixation. Consequently, the purpose of this study was to examine the production performance and energy transfer of leguminous crops and small millets. In the *Rabi*' seasons of 2021 to 2023 at the Agricultural College and Research Institute, Vazhavachanur, Tiruvannamalai, Tamil Nadu field experiments were conducted to investigate the intercropping of finger millet with blackgram and redgram with varied ratios under irrigated condition with seven treatments and three replications. It is inferred that the finger millet treatment with a 4:1 blackgram ratio performed significantly more photosynthetic efficiency or crop growth rate during the crop growth period. This system can be tried with other minor millets and other pulse crops for attaining better livelihood by small and marginal farmers under rain-fed cropping.

Keywords: Finger millet; Photosynthetic rate; Specific leaf weight; Crop growth rate; Source; Sink Capacity; Productivity

Abbreviations: TDMP: Total Dry Matter Production; IAA: Indole Acetic Acid

Introduction

Food grain production should be parallel with population growth in developing nations like India. Due to the limited area under cultivation, it is crucial to enhance production per unit area per unit time, which can only be accomplished by making use of the resources already with hand [1,2]. *Eleusine coracana*, or finger millet referred as ragi in Tamil Nadu, is a prominent millet crop being cultivated in India under a wide range of agroclimatic conditions to be utilised as grain and fodder. Due to its potent rejuvenating property, it subsequently reduces stress and is well suited for dry land farming. Intercropping is an effective approach for increasing the overall productivity per unit area per unit time while compared to sole cropping [3]. The main objectives of intercropping systems are to safeguard ecological balance, greater use of available resources, enhance quantity and quality of yield and minimises yield damage due to biological causes like weeds, pests, and diseases. Small millet-legume intercropping is a crop production technique that enhances soil fertility and quality by air circulation, water retention, and buffering constraints by adding organic matter to the soil (SOM) and increasing enzyme activity levels [4-6].

The concept of intercropping system involves growing two or more crops together with the assumption that two crops can exploit the environment better than one and ultimately produce higher yield because the component crops differ in phenotype, in resource use and when grown together, they complement each other and make overall better use of resources [7]. So, an experiment was planned with finger millet and legumes like black gram and red gram and to standardise varied intercropping ratios under rainfed condition. The main objective of this study was to determine the intercropping ratio and effects of blackgram with finger millet and redgram with finger millet cropping systems.

Materials and Methods

Field experiments were carried out to study the finger millet intercropping with blackgram and redgram under irrigated eco-system at Agricultural College and Research Institute, Vazhavachanur, Tiruvannamalai during 2021-22 and 2022-2023

Rabi' season under irrigated condition. Periodical observations were taken under the cropping period. This trial was planned with seven treatments *viz.,* T_1– Sole finger millet in row planting, T_2 – Finger millet with blackgram 3:1 ratio, T_3 – Finger millet with blackgram 3:2 ratio T_4– Finger millet with blackgram 4:1 ratio, T_5 – Finger millet with blackgram 4:2 ratio, T_6– Finger millet with redgram 6:1 ratio and T_7– Finger millet with redgram 8:1 ratio replicated thrice with randomised block design. Physiological observation *viz.,* photosynthetic rate, C_i / C_a and Indole Acetic Acid (IAA) oxidase activity were recorded at grain filling stage.

Total dry matter production (TDMP)

Plant samples were first shade dried and then oven dried at 70°C for 24 hours. The dry weight of the whole plant including the seeds was taken and expressed in g plant^{-1}.

Indole acetic acid (IAA) oxidase activity

The IAA oxidase activity of the leaf sample was estimated by the method proposed by Parthasarathy et al. [8] and the enzyme activity was expressed as µg of unoxidised auxin g^{-1} hr^{-1}.

Steady state poromeeter

Leaf photosynthetic rate, diffusive resistance and stomatal conductance, were measured on the youngest fully expanded, disease-free leaves in each plot with a Steady State Porometer (Li-Cor 3100) at the time of mid-noon period photosynthesis system.

Statistical method

Using the method outlined by Gomez and Gomez (1984), the data on numerous observations captured during the course of the inquiry were statistically analysed. In this study, combined data from 2021–2022 and 2022–2023 were examined.

Results and Discussion

Growing more than one crop together can change many components contributing yield by maintaining a stable genomic potential and adjusting environmental factors. Mostly, cultivation of ragi, intercropping blackgram and redgram is a rare practise. Cultivating legumes and cereals together is a popular intercropping strategy that offers many benefits for increased crop output [9]. The growth characteristics, such as plant height (95 and 53cm) (Table 1), root length (6.2 and 27.5cm) (Table 1), and number of branches (4.3 and 4) (Table 1), are found to increase when ragi with blackgram intercropped 4:1 ratio, followed by 4:2 and 3:1 ratio. The shading effect was responsible for the reduction in plant height and number of branches when ragi with redgram intercropped 6:1 and 8:1 ratio [10]. The finger millet sole crop and the finger millet intercropped with blackgram yielded the highest grain weight and yield among the different intercrops. Subsequently, leguminous crops also enhance the amount of nitrogen in the soil and aid in preserving soil fertility [11]. Finger millet with a 4:1 ratio has a tendency to allocate maximum plant height and root length, more tillers, and an efficient use of solar radiation; young leaves at the top absorb the most radiation and have a high assimilation of CO_2; the ratio between the CO2 levels in the atmosphere and the internal environment will also be higher (0.850 and 0.783µ mol CO_2 m^{-2} s^{-1}) (Table 1), and the stomatal diffusive resistance will also be higher (15.6 and 11.2 second cm^{-1}), which causes a translocation of large amounts of assimilate to other parts. In contrast, the canopy in overshadowed conditions had low rates of CO_2 absorption and contributes less to the assimilation of other plant components (3:2, 6:1, and 8:1). The highest efficiency of leaf photosynthesis occurs at low radiation levels, as measured by CO2 fixed per unit of light. A more uniform distribution of radiation throughout the leaf surfaces would increase the efficiency of finger millet intercropped with 4:1 ratio pulse (Figure 1). Agronomic research on intercropping small millets with leguminous crops is extensive. However, there is still more research to be done on the growth analysis, photosynthetic capacity, leaf area, crop growth rate, leaf size and leaf weight of the intercropped crops in relation to crop physiology. These parameters were focused on this research to obtain a fruitful result. Blackgram is a short-statured legume cover crop. The effect of nodulation potential had helped to fix more nitrogen in the soil, which is essential for the development of growth characteristics and the generation of dry matter overall. In a comparative study with single maize crop, the amounts of nitrogen, phosphorus, and potassium are increased with maize-cowpea intercropping [12].

Table 1: Evaluation of intercropping on plant height (cm). root length (cm), no of branches, stomatal diffusive resistance (second cm^{-1}) and C_i / C_a (µ mol CO_2 m^{-2} s$_{-1}$) of finger millet with pulses.

Treatments	Plant Height (cm)		Root Length (cm)		No of Branches		Stomatal Diffuse Resistance (SDR) (second cm^{-1})	
	Ragi	Intercrop*	Ragi	Intercrop*	Ragi	Intercrop*	Ragi	Intercrop
T_1- Sole finger millet in row planting	92	-	4.4	-	3.4	-	13.5	-
T_2 - Finger millet with blackgram 3:1 ratio	82	49	5.2	23.7	4.1	3	14.2	12.2
T_3 - Finger millet with blackgram 3:2 ratio	76	44	4.9	19.9	3.1	2.9	13.8	9.6
T_4 - Finger millet with blackgram 4:1 ratio	95	53	6.2	27.5	4.3	4	15.6	11.2
T_5 - Finger millet with blackgram 4:2 ratio	92	51	5.5	22.2	4.2	3.8	15.1	12.2
T_6- Finger millet with redgram 6:1 ratio	73	41	4.3	17.8	3.2	8.6	10.7	10.9
T_7- Finger millet with redgram 8:1 ratio	70	39	4	16.1	2.7	8.3	9.5	9.8
SEm	2.24	-	0.17	-	0.17	-	0.22	0.48
CD (P=0.05)	6.91	-	0.52	-	0.52	-	0.68	1.51

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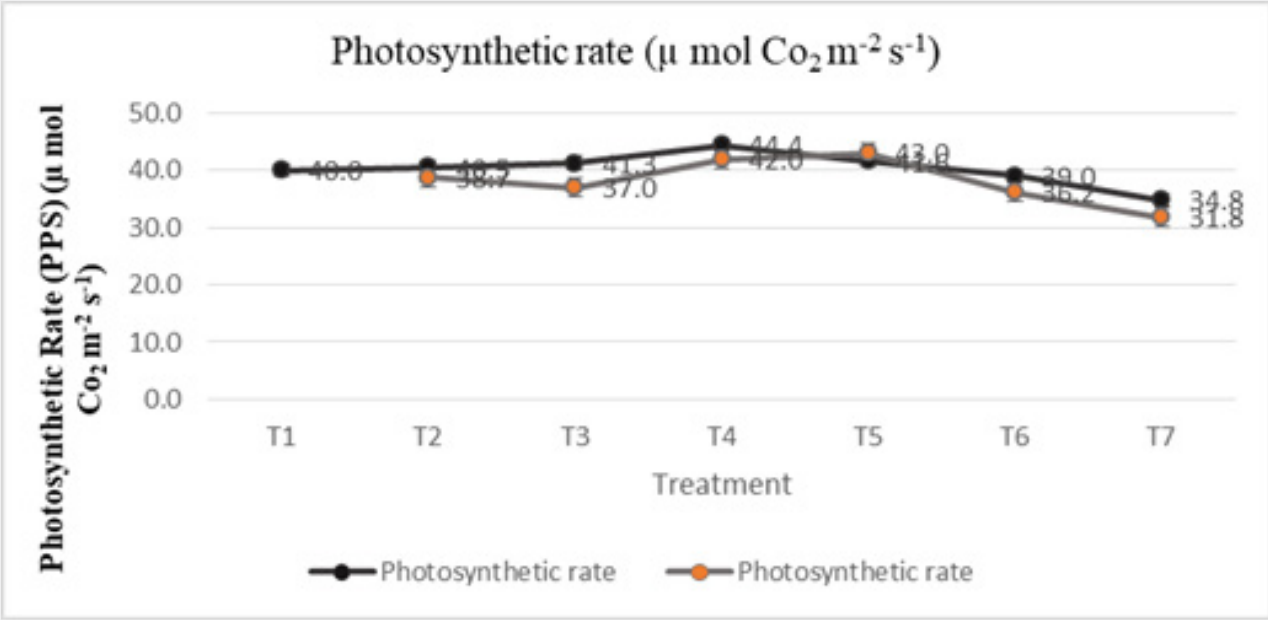

Figure 1: Intercropping effect on Photosynthetic Rate (PPS) (μ mol Co2 m^{-2} s^{-1}) in fingermillet with pulses.

IAA oxidase activity, which is an essential enzyme analysis used to regulate plant growth and development. Since the indole acetic acid concentration is known to quantitatively determine the level of growth accomplished through the cell and the elongation of plant cells is known to be hormonally regulated by IAA. IAA levels are typically lower in crops prior to the onset of flowering [13]. This paper focuses on examining the topographical distribution of IAA oxidase activity in finger millet along with how intercropping blackgram at a 4:1 ratio promotes the enzyme's activity in comparison to other treatments (Figure 2).

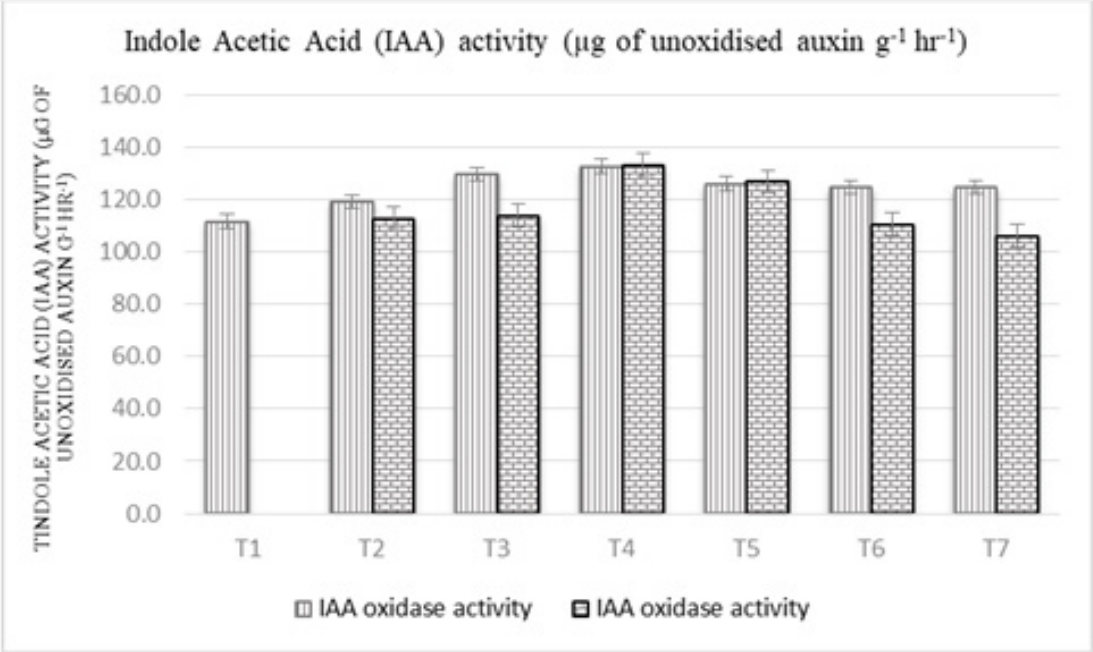

Figure 2: Intercropping effect on IAA oxidase activity (μg of unoxidised auxin g-1hr^{-1}) in fingermillet with pulses.

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Out of all the intercrops, finger millet as a sole crop and finger millet intercropped with blackgram yielded the highest production of dry matter. However, when redgram was intercropped with finger millet, the opposite response was observed. Because red gram's indeterminate growth created more tillers, busy growth has the potential to impact the growth of finger millet, tiller numbers and the overall production of dry matter. According to an on-farm experiment conducted in South Odisha's Koraput, intercropping finger millet with pigeon pea in a replacement series decreased finger millet production compared to pure stand [14]. The study showed a major alteration in the dry matter production irrespective of the intercropping. The treatment finger millet with blackgram 4:1 recorded maximum dry matter production (25.3), followed by finger millet with blackgram 3:1 ratio (23.2). When finger millet is interplanted with blackgram (finger millet with blackgram 4:1 ratio), it is seen that the yield parameters of finger millet, such as the number of clusters per plant (6.80) and the number of pods per cluster (7.1), increase. At harvest, the 4:1 ratio with blackgram intercrops had a considerable impact on the grain output of finger millet, which was 2486kg ha^{-1} (Table 2). The treatment with finger millet with blackgram 4:1 had 2054kg ha^{-1} and finger millet with blackgram 3:1 had 1998 kg ha^{-1} recorded the maximum grain yield of finger millet. The study conducted by Sharma & Singh [15] found that the intercropping or strip cropping of leguminous crops, such as green gram, cluster bean, and cowpea, in a row ratio ranging from 2:1 to 8:4, did not significantly reduce the grain production of pearl millet. When millet and cowpea were planted in a 1:1 or 2:1 ratio, Yirzagla [16] found that the millet grain output was much higher than the average yield of 1.74t ha^{-1} [17-39].

Table 2: Evaluation of intercropping on Total Dry Matter Accumulation (g $plant^{-1}$), Days to flowering, Number of clusters per plant, No of fingers / pods per plant, and grain yield (kg/ha) of finger millet with pulses.

Treatments	Ci/Ca (µ mol CO_2 m^{-2} s^{-1})		TDMA (g $plant^{-1}$)		Days to Flowering		Grain Yield (kg/ha)	
	Ragi	Intercrop	Ragi	Intercrop*	Ragi	Intercrop*	Ragi	Intercrop*
T_1- Sole finger millet in row planting	0.761	-	20.3	19.13	71	45.6	1843	2486
T_2-Finger millet with blackgram 3:1 ratio	0.733	0.686	23.2	26.05	65	30.2	1998	2583
T_3 - Finger millet with blackgram 3:2 ratio	0.667	0.669	21.6	24.52	64	31.6	1720	2864
T_4- Finger millet with blackgram 4:1 ratio	0.85	0.783	25.3	28.31	68	29.8	2054	3055
T_5 - Finger millet with blackgram 4:2 ratio	0.778	0.672	23	21.51	68	31.8	1865	2758
T_6- Finger millet with redgram 6:1 ratio	0.666	0.625	20.6	21.14	62	58.4	1265	1746
T_7- Finger millet with redgram 8:1 ratio	0.622	0.575	19.6	19.5	60	62.6	1077	1477
SEm	0.01	-	0.65	-	0.33	-	75.6	-
CD (P=0.05)	0.03	-	1.99	-	1.03	-	232.9	-

*Data not statistically analysed for C_i / C_a, Total Dry Matter Accumulation, Days to flowering and grain yield for both pulse crop.

Conclusion

The strength of the grain as a sink is known as assimilate partitioning, and as previously mentioned, the main and intercrop competition between plant density, light interception, crop growth rate, total dry matter output, and chlorophyll content may be impacted by the availability and strength of sources. There has not been enough physiological study done on the intercropping of finger millet and blackgram presently. Black gram density causes potential fruits and flowers to either not set or to abort. It is inferred that the finger millet treatment with a 4:1 blackgram ratio performed significantly during the crop growth period. This productive ratio can be well tested in rainfed conditions and in less fertile soil with other millet crops and leguminous crop combinations for enhanced yield and effective cost benefit ratio. However, an analysis of the physiological impacts of a finger millet-based intercropping system can be beneficial to small farmers' dryland agriculture.

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