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EVALUATING THE PHYSIOLOGICAL IMPACT OF BIOFERTILIZERS AND RECOMMENDED FERTILIZER DOSES ON CHINA ASTER (*CALLISTEPHUS CHINENSIS* L. NEES) CV. ARKA KAMINI IN COASTAL ANDHRA PRADESH INDIA

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ABSTRACT

China Aster [*Callistephus chinensis* (L.) Nees], a commercial winter flowering annual in Southern part of India, belongs to Asteraceae family and have originated in China. An experiment was carried out in coastal region of Andhra Pradesh to know the efficacy of biofertilizers *Azospirillum*, Phosphate Solubilizing Bacteria (PSB), and Potassium Mobilizing Bacteria (KMB) in conjunction with recommended fertilizer doses (RDF) on the physiological parameters of China Aster cv. Arka Kamini. All the physiological parameters like Absolute Growth Rate (AGR), Crop Growth rate (CGR), Relative Growth Rate (RGR), Net Assimilation Rate (NAR) and Leaf Area Duration (LAD) where significantly high during the period of 30-60 days after planting and were lowered in the period of 60-90 days. The parameters RGR and NAR not only decreased during 60-90 days, but also became negative in magnitude. The findings indicate that the combination of 100% RDF with biofertilizers *Azospirillum* @ 4 kg acre^{-1} + PSB @ 4 kg acre^{-1} + KMB @ 4 kg acre^{-1}outperformed other treatments, enhancing plant performance.
Keywords **:** China Aster, Biofertilizers, Absolute Growth Rate, Relative Growth Rate and Net Assimilation Rate

Introduction

China Aster [*Callistephus chinensis* (L.) Nees] is a winter flowering annual renowned for its vibrant blooms, belonging to the plant family Asteraceae and native to China (Kumari *et al*., 2017). This attractive flower holds significant importance as loose flowers, cut flowers and in potted arrangements. Commercial cultivation of China Aster predominantly thrives in the southern states of India, notably Karnataka, Tamil Nadu and Andhra Pradesh (Khangjarakpam *et al*., 2016), where favourable climates foster its growth with skill. However, recent trends in cultivation have seen an unfortunate reliance on chemical fertilizers as growers strive to maximize yields and due to the indiscriminate application of chemical fertilizers poses adverse effects on soil health and ecosystem balance (Shukla *et al*., 2022). Overdosing with synthetic fertilizers leads to deleterious effects on both the physical and chemical properties of the soil, disrupting its natural equilibrium and hinders the growth of essential microbials vital for nutrient cycling and soil fertility (Pahalvi *et al*., 2021).

Biofertilizers are compounds containing beneficial microorganisms that establish symbiotic relationship with rhizosphere of the host plants, aiding in the uptake of essential nutrients (Sashoo *et al*., 2012). They transform nutrients from unavailable to available forms, facilitating their absorption by the host plant. Several commercially available biofertilizers include *Azospirillum*, Phosphate-Solubilizing Bacteria (PSB) and potassium-mobilizing bacteria (KMB) (Karri and Nalluri, 2021). The present experiment was conducted in the coastal region of Andhra Pradesh, a commercial cultivar of China Aster, known as Arka Kamini released by IIHR which has attractive pink flowers and demonstrates high yield potential, was utilized (Veluru *et al.*, 2022). The experiment aimed to evaluate the efficacy of various biofertilizers, viz., *Azospirillum*, PSB and KMB, at different levels in combination with different doses of Recommended Fertilizer (RDF) *i.e.*, 180: 120: 60 NPK Kg/ha (Munikrishnappa and Chandrashekar, 2014), on the physiological parameters in the coastal region of Andhra Pradesh.

Materials and Methods

The present experiment was carried out at the instructional farm of College of Horticulture, Venkaramannagudem, West Godavari, Andhra Pradesh. The experiment was laid out in Factorial Randomized Block Design (FRBD) which has two replications and two factors. The Factor-I consists of five levels of RDF *viz.*, F_1- 80% NPK (144 : 96 : 48 Kg ha^{-1}), F_2- 90% NPK (162 : 108 : 54 Kg ha^{-1}), F_3- 100% NPK (180 : 120 : 60 Kg ha^{-1}), F_4- 110% NPK (198 : 132 : 66 Kg ha^{-1}) and F_5- 120% NPK (216 : 144 : 72 Kg ha^{-1}) and the Factor-II consists of three levels of biofertilizers *viz.*, B_1- *Azospirillum* @ 2 kg acre^{-1} + PSB @ 2 kg acre^{-1} + KMB @ 2 kg acre^{-1}, B_2- *Azospirillum* @ 3 kg acre^{-1} + PSB @ 3 kg acre^{-1} + KMB @ 3 kg acre^{-1} and B_3- *Azospirillum* @ 4 kg acre^{-1} + PSB @ 4 kg acre^{-1} + KMB @ 4 kg acre^{-1}. Well grown seedlings are planted in the experimental plots at spacing of 30cm × 30cm and after three days of establishment biofertilizer combinations were given at the rhizosphere of the plants. After seven days different RDF levels were given according to the treatment combination. The various physiological parameters were taken from the below mentioned formulas-

Absolute Growth Rate (cm d^{-1}): (Hunt and Hunt, 1990)

$$AGR = \frac{h_2 - h_1}{t_2 - t_1}$$

Where, h_1 and h_2 are the plant heights at times t_1 and t_2 respectively.

Crop Growth Rate (g m^{-2}d^{-1}): (Pandey *et al.*, 2015)

$$CGR = \frac{w_2 - w_1}{t_2 - t_1} \times \frac{1}{P}$$

Where, W_1 and W_2 are whole plant dry weights at times t_1 and t_2 respectively and P is the land area.

Relative Growth Rate (mg mg^{-1} d^{-1}): (Junttila, 1970)

$$RGR = \frac{Logew_2 - Logew_1}{t_2 - t_1}$$

Where, $LogeW_1$ and $LogeW_2$ are logarithms of dry weights at times t_1 and t_2 respectively.

Net Assimilation Rate (mg cm^{-2} d^{-1}): (Righetti *et al.*, 2007)

$$NAR = \frac{w_2 - w_1}{t_2 - t_1} \times \frac{LogeA_2 - LogeA_1}{A_2 - A_1}$$

Where, W_1 and W_2 are whole plant dry weights at times t_1 and t_2 respectively.

Loge A_1 and Loge A_2 are logarithms of leaf area, A_1 and A_2 are the leaf areas at times.

Leaf Area Duration (cm^2 d^{-1}): (Li *et al.*, 2022)

$$LAD = \frac{\Delta A}{lnA_2 - lnA_1} \times \frac{1}{\Delta t}$$

Where, ΔA = Differences in total leaf area plant^{-1} in cm^2

ln A^1, ln A^2 are the natural logarithms of leaf areas plant^{-1} at times t_1 and t_2 respectively.

Δt = Differences in time interval (d)

Results

Absolute Growth Rate (AGR)

Significant differences were observed among different NPK levels regarding absolute growth rate (AGR) at all recorded observation dates. The highest AGR was noted at 100% RDF (1.328 and 0.348 cm d^{-1} at 30-60 and 60-90 DAT, respectively), followed by 110% RDF (1.208 and 0.301 cm d^{-1}). The lowest AGR was at 80% RDF (0.935 and 0.134 cm d^{-1}). AGR increased from 30-60 DAT and decreased from 60-90 DAT due to slower plant height growth. Bio-fertilizers significantly influenced AGR, with *Azospirillum* @ 4 kg acre^{-1} + PSB @ 4 kg acre^{-1} + KMB @ 4 kg acre^{-1} showing the highest AGR (1.150 and 0.264 cm d^{-1}) and *Azospirillum* @ 2 kg acre^{-1} + PSB @ 2 kg acre^{-1} + KMB @ 2 kg acre^{-1} the lowest (1.076 and 0.228 cm d^{-1}). The interaction effect of 100% RDF with *Azospirillum* @ 4 kg acre^{-1} + PSB @ 4 kg acre^{-1} + KMB @ 4 kg acre^{-1} yielded the maximum AGR (1.381 and 0.358 cm d^{-1}), while the minimum was in 80% RDF with *Azospirillum* @ 2 kg acre^{-1} + PSB @ 2 kg acre^{-1} + KMB @ 2 kg acre^{-1} (0.920 and 0.125 cm d^{-1}).

Table 1: Effect of NPK, bio-fertilizer levels and their interaction on Absolute Growth Rate in China Aster [*Callistephus chinensis* (L.) Nees] cv. Arka Kamini

Absolute Growth Rate (cm d^{-1})						
	30-60 DAP					
	F1	F2	F3	F4	F5	Mean
B1	0.920	0.959	1.286	1.147	1.070	**1.076**
B2	0.933	0.976	1.316	1.220	1.092	**1.107**
B3	0.953	1.017	1.381	1.258	1.140	**1.150**
Mean	**0.935**	**0.984**	**1.328**	**1.208**	**1.101**	**1.111**
Factor	**SEm±**			**CD at 5%**		
F	0.026			0.080		
B	0.020			0.062		
F x B	0.046			0.138		
	60-90 DAP					
	F1	F2	F3	F4	F5	Mean
B1	0.125	0.147	0.331	0.282	0.253	**0.228**
B2	0.134	0.151	0.355	0.308	0.272	**0.244**
B3	0.142	0.228	0.358	0.312	0.281	**0.264**
Mean	**0.134**	**0.175**	**0.348**	**0.301**	**0.269**	**0.245**
Factor	**SEm±**			**CD at5%**		
F	0.010			0.030		
B	0.008			0.023		
F x B	0.017			0.052		

Crop Growth Rate (g m^{-2} d^{-1}):

During the period of 30-60 days after transplanting (DAT), no notable variations were evident among the different levels of RDF. Among these RDF levels, plants treated with 100% RDF exhibited the highest crop growth rate (0.838 and -0.165 g m^{-2} d^{-1} at 30-60 and 60-90 DAT, respectively), followed by those treated with 110% RDF (0.801 and -0.196 g m^{-2} d^{-1} at 30-60 and 60-90 DAT, respectively). The lowest crop growth rate (0.765 and -0.330 g m^{-2} d^{-1} at 30-60 and 60-90 DAT, respectively) was observed in the treatment with 80% RDF. The application of various levels of bio-fertilizers resulted in significant differences with respect to crop growth rate at 60-90 DAT. During the period of 30-60 DAT, all the bio-fertilizers exhibited similar performance. However, plants treated with *Azospirillum* @ 4 kg $acre^{-1}$ + PSB @ 4 kg $acre^{-1}$ + KMB @ 4 kg $acre^{-1}$ showed the highest crop growth rate (0.804 and -0.165 g m^{-2} d^{-1} at 30-60 and 60-90 DAT, respectively), and the lowest crop growth rate (0.783 and -0.209 g m^{-2} d^{-1} at 30-60 and 60-90 DAT, respectively) was observed in the treatment with *Azospirillum* @ 2 kg $acre^{-1}$ + PSB @ 2 kg $acre^{-1}$ + KMB @ 2 kg $acre^{-1}$. A continuous rise in crop growth rate was observed in the treatment with *Azospirillum* @ 4 kg $acre^{-1}$ + PSB @ 4 kg $acre^{-1}$ + KMB @ 4 kg $acre^{-1}$ up to 60 DAT. During the 30-60 DAT period, all interactions demonstrated similar growth rates. The highest crop growth rate was observed in the interaction of 100% RDF with *Azospirillum* @ 4 kg $acre^{-1}$ + PSB @ 4 kg $acre^{-1}$ + KMB @ 4 kg $acre^{-1}$, which was comparable to the interactions of 110% RDF with the same treatments (0.803 and -0.180 g m^{-2} d^{-1} at 30-60, 60-90 DAT, respectively) and 120% RDF with the same treatments (0.791 and -0.209 g m^{-2} d^{-1} at 30-60, 60-90 DAT, respectively). The lowest growth rate was observed in the interaction of 80% RDF with *Azospirillum* @ 2 kg $acre^{-1}$ + PSB @ 2 kg $acre^{-1}$ + KMB @ 2 kg $acre^{-1}$ (0.740 and -0.457 g m^{-2} d^{-1} at 30-60, 60-90 DAT, respectively).

Relative Growth Rate (mg mg^{-1} d^{-1}):

Plants that received 100% RDF exhibited the highest relative growth rate (0.039 and -6.30 mg mg^{-1} d^{-1} at 30-60 and 60-90 DAT, respectively) and the lowest relative growth rate (0.023 and -6.77 mg $mg^{-1}d^{-1}$ at 30-60 and 60-90 DAT, respectively) was observed in the treatment with 80% RDF. The application of bio-fertilizers did not significantly impact the relative growth rate. Plants treated with *Azospirillum* @ 4 kg $acre^{-1}$ + PSB @ 4 kg $acre^{-1}$ + KMB @ 4 kg $acre^{-1}$ exhibited the highest relative growth rate (0.032 and -6.49 mg mg^{-1} d^{-1} at 30-60 and 60-90 DAT, respectively) and the lowest relative growth rate (0.030 and -6.55 mg mg^{-1} d^{-1} at 30-60 and 60-90 DAT, respectively) in the treatment with *Azospirillum* @ 2 kg $acre^{-1}$ + PSB @ 2 kg $acre^{-1}$ + KMB @ 2 kg $acre^{-1}$. The interaction effect between NPK and bio-fertilizer levels was significant with respect to relative growth rate. Plants treated with 100% RDF and *Azospirillum* @ 4 kg acre^{-1} + PSB @ 4 kg acre^{-1} + KMB @ 4 kg acre^{-1} recorded the highest relative growth rate (0.40 and -6.27 mg mg^{-1}d^{-1} at 30-60 and 60-90 DAT, respectively) and the lowest relative growth rate (0.022 and -6.81 mg mg^{-1}d^{-1} at 30-60 and 60-90 DAT, respectively) in the interaction between 80% RDF and *Azospirillum* @ 2 kg acre^{-1} + PSB @ 2 kg acre^{-1} + KMB @ 2 kg acre^{-1}.

Table 2: Effect of NPK, bio-fertilizer levels and their interaction on Crop Growth Rate in China Aster [*Callistephus chinensis* (L.) Nees] cv. Arka Kamini

Crop growth rate (g m^{-2} d^{-1})						
	30-60 DAP					
	F1	F2	F3	F4	F5	Mean
B1	0.740	0.781	0.813	0.797	0.786	**0.783**
B2	0.777	0.784	0.837	0.802	0.787	**0.797**
B3	0.779	0.785	0.863	0.803	0.791	**0.804**
Mean	**0.765**	**0.783**	**0.838**	**0.801**	**0.788**	**0.795**
Factor	**SEm±**			**CD at 5%**		
F	0.042			0.129		
B	0.033			0.100		
F x B	0.074			0.223		
	60-90 DAP					
	F1	F2	F3	F4	F5	Mean
B1	-0.457	-0.252	-0.177	-0.208	-0.227	**-0.264**
B2	-0.274	-0.251	-0.163	-0.199	-0.214	**-0.220**
B3	-0.260	-0.240	-0.155	-0.180	-0.209	**-0.209**
Mean	**-0.330**	**-0.248**	**-0.165**	**-0.196**	**-0.217**	**-0.231**
Factor	**SEm±**			**CD at 5%**		
F	0.042			0.129		
B	0.033			0.100		
F x B	0.074			0.223		

Table 3: Effect of NPK, bio-fertilizer levels and their interaction on Relative Growth Rate in China Aster [*Callistephus chinensis* (L.) Nees] cv. Arka Kamini

Relative growth rate (mg mg^{-1} d^{-1})						
	30-60 DAP					
	F1	F2	F3	F4	F5	Mean
B1	0.022	0.026	0.038	0.034	0.030	**0.030**
B2	0.023	0.027	0.039	0.036	0.031	**0.031**
B3	0.024	0.028	0.040	0.037	0.032	**0.032**
Mean	**0.023**	**0.027**	**0.039**	**0.036**	**0.031**	**0.031**
Factor	**SEm±**			**CD at 5%**		
F	0.001			0.002		
B	0.001			0.002		
F x B	0.001			0.004		
	60-90 DAP					
	F1	F2	F3	F4	F5	Mean
B1	-6.81	-6.67	-6.32	-6.41	-6.53	**-6.55**
B2	-6.76	-6.62	-6.31	-6.39	-6.51	**-6.52**
B3	-6.73	-6.60	-6.27	-6.36	-6.48	**-6.49**
Mean	**-6.77**	**-6.63**	**-6.30**	**-6.39**	**-6.51**	**-6.52**
Factor	**SEm±**			**CD at 5%**		
F	0.020			0.061		
B	0.016			0.047		
F x B	0.035			0.106		

Net Assimilation Rate (mg cm^{-2} d^{-1}):

The results of the study revealed that plants treated with 100% RDF demonstrated the highest net assimilation rate, which was 0.328 and -0.119 mg cm^{-2} d^{-1} at 30-60 and 60-90 DAT, respectively. On the other hand, the minimum net assimilation rate was recorded in the treatment with 80% RDF, which was 0.255 and -0.048 mg cm^{-2} d^{-1} at 30-60 and 60-90 DAT, respectively. Significant differences were observed among the bio-fertilizers for net assimilation rate. The treatment with *Azospirillum* @ 4 kg acre^{-1} + PSB @ 4 kg acre^{-1} + KMB @ 4 kg acre^{-1} recorded the highest net assimilation rate, which was 0.291 and -0.086 mg cm^{-2} d^{-1} at 30-60 and 60-90 DAT, respectively. This was comparable to the treatment with *Azospirillum* @ 3 kg acre^{-1} + PSB @ 3 kg acre^{-1} + KMB @ 3 kg acre^{-1}, which had a net assimilation rate of 0.286 and -0.083 mg cm^{-2} d^{-1} at 30-60 and 60-90 DAT, respectively. The lowest net assimilation rate, which was 0.282 and -0.076 mg cm^{-2} d^{-1} at 30-60 and 60-90 DAT, respectively, was recorded in the treatment with *Azospirillum* @ 2 kg acre^{-1} + PSB @ 2 kg acre^{-1} + KMB @ 2 kg acre^{-1}. The interaction effect of 100% RDF with *Azospirillum* @ 4 kg acre^{-1} + PSB @ 4 kg acre^{-1} + KMB @ 4 kg acre^{-1} resulted in the highest net assimilation rate, which was 0.331 and -0.123 mg cm^{-2} d^{-1} at 30-60 and 60-90 DAT, respectively. The lowest net assimilation rate, which was 0.250 and -0.044 mg cm^{-2} d^{-1} at 30-60 and 60-90 DAT, respectively, was recorded in the interaction between 80% RDF and *Azospirillum* @ 2 kg acre^{-1} + PSB @ 2 kg acre^{-1} + KMB @ 2 kg acre^{-1}.

Table 4 : Effect of NPK, bio-fertilizer levels and their interaction on Net Assimilation Rate in China Aster [*Callistephus chinensis* (L.) Nees] cv. Arka Kamini

Net Assimilation Rate (mg cm^{-2} d^{-1})						
	30-60 DAP					
	F1	F2	F3	F4	F5	Mean
B1	0.250	0.261	0.326	0.299	0.274	**0.282**
B2	0.256	0.267	0.327	0.304	0.277	**0.286**
B3	0.259	0.268	0.331	0.314	0.282	**0.291**
Mean	**0.255**	**0.265**	**0.328**	**0.306**	**0.278**	**0.286**
Factor	**SEm±**				**CD at 5%**	
F	0.003				0.010	
B	0.003				0.008	
F x B	0.006				0.017	
	60-90 DAP					
	F1	F2	F3	F4	F5	Mean
B1	-0.044	-0.059	-0.114	-0.090	-0.073	**-0.076**
B2	-0.050	-0.062	-0.119	-0.103	-0.079	**-0.083**
B3	-0.051	-0.065	-0.123	-0.108	-0.082	**-0.086**
Mean	**-0.048**	**-0.062**	**-0.119**	**-0.100**	**-0.078**	**-0.081**
Factor	**SEm±**			**CD at 5%**		
F	0.003			0.010		
B	0.002			0.007		
F x B	0.005			0.017		

Plants receiving the full recommended fertilizer dose demonstrated the most prolonged period of leaf expansion, measuring an average of 43.81 and 38.61 cm^2 per day during the 30-60 and 60-90 post-application intervals, respectively. In comparison, those given a 10% higher than recommended dosage exhibited slightly lower durations, with 40.68 square centimeters per day between 30-60 days and 35.64 cm^2 per day between 60-90 days. Conversely, the plants subjected to an 80% dose of the standard recommendation experienced the shortest average duration, with leaf areas expanding at rates of 31.01 and 26.01 cm^2 per day in the same respective intervals. Diverse bio-fertilizer treatments also significantly affected the length of time the leaves continued to expand. Notably, plants enhanced with a blend of bio-fertilizers containing *Azospirillum*, Phosphate Solubilizing Bacteria, and Potassium Mobilizing Bacteria, each at 4 kg per acre, achieved leaf expansion rates comparable to those treated with 100% RDF. They exhibited an average leaf area of 38.78 and 33.62 cm^2 per day during the initial and later intervals, respectively. The most modest expansion was found in plants treated with the bio-fertilizer mixture at 2 kg per acre. Synergistic effects became evident when looking at the combination of 100% RDF along with the highest concentration of bio-fertilizers. This particular interaction led to the highest observed rates of leaf area expansion. However, the same bio-fertilizer mixture applied with an 80% RDF significantly limited this growth, leading to the smallest leaf area duration noted within the study (Kammerlocher, 2010) (DeCleene & Fogo, 2012).

Table 5: Effect of NPK, bio-fertilizer levels and their interaction on Leaf Area Duration in China Aster [*Callistephus chinensis* (L.) Nees] cv. Arka Kamini

Leaf Area Duration (LAD) ($cm^2 d^{-1}$)						
	30-60 DAP					
	F1	F2	F3	F4	F5	Mean
B1	29.03	33.84	42.78	40.16	38.00	**36.76**
B2	31.89	34.92	43.33	40.34	38.75	**37.85**
B3	32.11	35.62	45.33	41.54	39.29	**38.78**
Mean	**31.01**	**34.79**	**43.81**	**40.68**	**38.68**	**37.80**
Factor	**SEm±**			**CD at 5%**		
F	0.66			1.99		
B	0.51			1.54		
F x B	1.14			3.45		
	60-90 DAP					
	F1	F2	F3	F4	F5	Mean
B1	23.75	28.61	37.78	34.89	32.42	**31.49**
B2	26.54	29.12	38.62	35.49	33.98	**32.75**
B3	27.74	30.11	39.44	36.55	34.27	**33.62**
Mean	**26.01**	**29.28**	**38.61**	**35.64**	**33.56**	**32.62**
Factor	**SEm±**			**CD at 5%**		
F	0.66			2.00		
B	0.51			1.55		
F x B	1.14			3.47		

Relationship between 30-60 Days and 60-90 Days for AGR, CGR, RGR, NAR and LAD across different treatments:

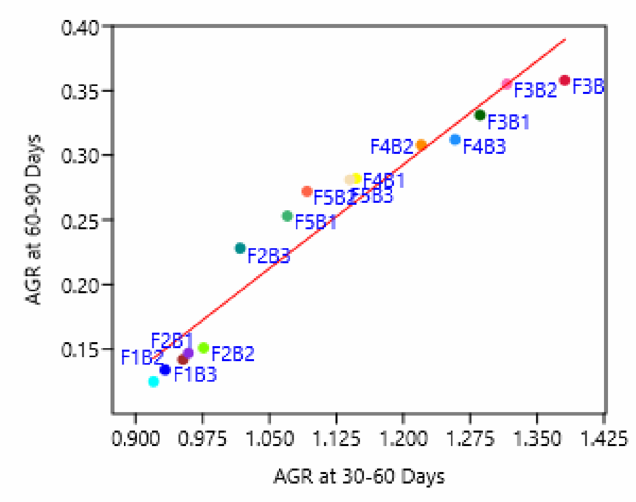

Fig. 1: AGR

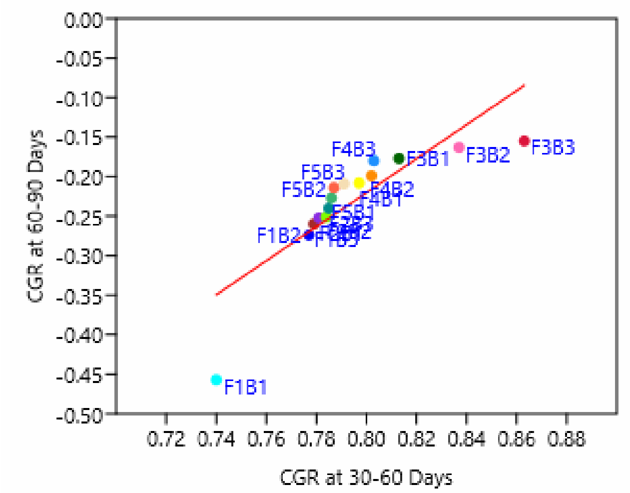

Fig. 2: CGR

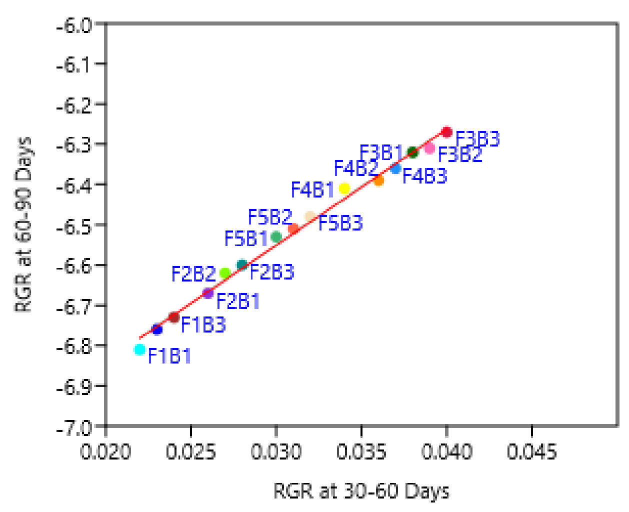

Fig. 3: RGR

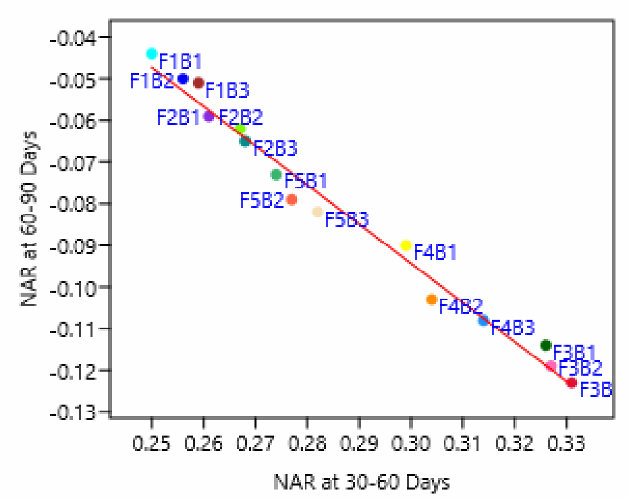

Fig. 4: NAR

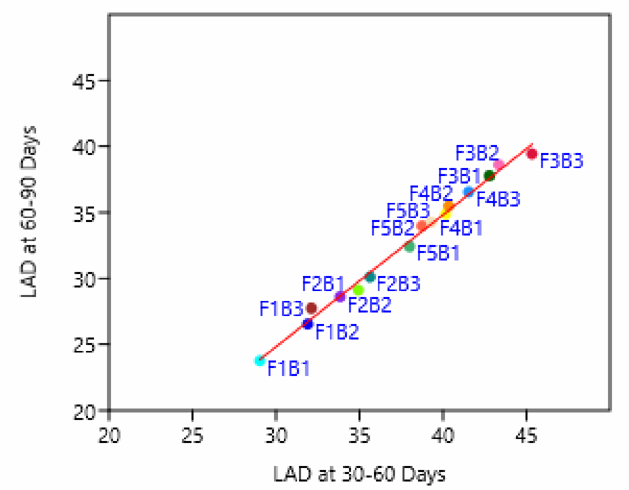

Fig. 5: LAD

Discussion

Several studies have been examined the synergistic effect of combinations of different biofertilizers on crop growth and development. The present study revealed that the combined effect of different biofertilizer combinations along with different RDF levels which was significantly more than the individual effects. The process through which this synergistic effect is achieved is complex and multifaceted (Arora *et al.*, 2013). *Azospirillum* is capable of fixing atmospheric nitrogen, which makes it more accessible to plants (Okumura *et al.*, 2013). Additionally, phosphate-solubilizing and potassium-mobilizing bacteria help to increase the availability of essential macronutrients such as phosphate and potassium (Sindhu *et al.*, 2013). Furthermore, biofertilizers can also generate plant growth-promoting substances, such as indole acetic acid (IAA) and gibberellins, which may stimulate plant growth and development (Noumavo *et al.*, 2016). IAA helps in increased cell division, root initiation and vigorous branching (Saini *et al.*, 2013). While, gibberellins enhance cell elongation which leads to increased plant growth (Tanimoto, 2005). When inorganic fertilizers were applied along with biofertilizers, the nutrient availability will be significantly increased, promoting rapid growth of the plant (Jilani *et al.*, 2007). The increased nutrient availability highers the rate of photosynthesis and metabolic activities, thereby ensures adequate supply of ATP for various growth aspects (Reddy *et al.*, 2004). As the plant matures, the nutrients were redistributed within the plant to support reproductive development and lowers the growth rates (Brant and Chen, 2015). All the above discussed parameters have reduced at 60-90 days when compared to 30-60 days and it is noteworthy that the relative growth rate exhibited an increase from 30-60 days and subsequently experienced a decline, ultimately becoming negative (Poorter and Navas, 2003). The relative growth rate pertained to the rate at which dry matter was produced per unit of existing dry matter in the plant. From 30-60 days, the relative growth rate displayed an upswing, but subsequent to that, it diminished due to the prevalence of structural tissue development as opposed to photosynthetic tissue development (Unterholzner *et al.*, 2022). Subsequently, it was discovered that over time, the dry weight of the plant diminished as a result of the translocation of photoassimilates to the reproductive organs as opposed to structural organ development (Gifford *et al.*, 1984). The Net Assimilation Rate (NAR) was elevated 30-60 days after transplanting (DAT) and subsequently decreased, turning negative in value. The drop in NAR at 90 days after planting (DAP) could be related to a decline in leaf area index, plant dry weight, and reduction in total leaf chlorophyll content, as well as decreased photosynthetic activity in the lower canopy leaves (Boote and Loomis, 1991). The decrease in the leaf area index, total chlorophyll content decreased the leaf area duration was observed at 90 DAT. It could be due to lack of production functional leaves per plant, ageing and senescence (Johnson and Thornley, 1983) of the matured leaves had been observed in all the treatments at 90 DAT.

Conclusion

The combined effects of RDF and biofertilizers were found to be superior to the individual effects. Among the treatment combinations, the application of 100% RDF along with *Azospirillum* @ 4 kg acre^{-1} + PSB @ 4 kg acre^{-1} + KMB @ 4 kg acre^{-1} performed best in all physiological parameters, even though the same biofertilizer concentrations were applied with 120% of RDF. However, all the physiological parameters decreased between 60-90 days compared to 30-60 days and the parameters Relative Growth Rate and Net Assimilation Rate showed negative exponential growth between 60-90 days. From this experiment, it can be concluded that the combination of 100% RDF with *Azospirillum* @ 4 kg acre^{-1} + PSB @ 4 kg acre^{-1} + KMB @ 4 kg acre^{-1} is the preferred for cultivating China Aster cv. Arka Kamini in the coastal region of Andhra Pradesh.

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