Fertigation Scheduling for Protected Cultivation of Capsicum and Cucumber

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Abstract

Experiments were conducted to study the effect of fertigation on Capsicum and Cucumber under protected cultivation during kharif season, with fertigation treatments applied through water soluble fertilizer (19:19:19) in randomized block design with four replications. fertigation under protected cultivation with capsicum and cucumber fetched higher yield and higher income. It can be concluded that fertigation with water soluble fertilizer @ 120 kg ha^{-1} and 60 kg ha^{-1} registered significantly higher fruit yield, net return and Benefit Cost ratio in capsicum and cucumber respectively. Higher cucumber fruit yield was recorded in the treatment that received WSF @ 80, 120, 160, 200 kg ha^{-1} compared to the treatment that received 100% RDF as straight fertilizer. The fertilizer use efficiency in capsicum was higher with lower levels of nutrients applied in the form of water soluble fertilizers , fertigation @ 80 kg WSF ha^{-1} compared to higher doses of nutrient application.

Keywords: Capsicum, Cucumber, Fertigation, Fruit yield, Economics, FUE, AE

1. Introduction

Capsicum belongs to the Night shade family Solanaceae and is supposed to be originated in the Tropical South America (Shoemaker and Teskey, 1995). Capsicum is high value low volume crop cultivated natural and protected conditions in India (Nikki et al., 2017) and very popular in Indian foods because of its appealing food value along with rich vitamins and minerals (Kurubetta and Patil, 2009).

Protected cultivation is a cutting edge technology where partial to full control over environmental parameters can be achieved (Baghelet al., 2003, Navale et al., 2003, Wani et al., 2011). Due to the optimum plant stature, canopy cover and bearing of flower and fruit at comparatively lower temperature capsicum is very much suitable to greenhouse growing (Singh et al., 2005)

Cucumbers grown under protection are more productive and of higher quality than those grown in the open. For year-round cucumber cultivation, the less expensive naturally ventilated greenhouses are more practical and cost-effective (Singh et al.2007)

An approach of protected cropping using low- (poly tunnels, net houses, screen houses) medium- (semi automated poly houses and glasshouses), and high-tech (highly automated glasshouses) greenhouses to grow different types of crops (Abdalla *et al*., 2022) is a potential solution.

Appropriate fertigation management in protected cropping is critical for improving crop quality, minimizing water and fertilizer use and reducing leaching beneath root depth (Hasanuzzaman *et al*., 2018). The ability of plants to selectively take up nutrients according to different nutritional needs at different growth stages optimizes plant growth in a precise manner (Neocleous and Savvas, 2022).

Cost ratio of 2.17 (Tumbare and Bhoite 2002) when N, P, K water soluble fertilizers were applied as fertigation, through drip irrigation system in capsicum. The optimum yield of pepper was obtained from sole application of NPK at 250 kg NPK ha^{-1} (Olaniyi and Ojetayo 2010).

Ciba (2011) observed that drip fertigation with 100 per cent water soluble fertilizer along with Bio stimulants recorded highest plant height, number of primary and secondary branches, number of flowers/plant and yield and component characters. Commercial fertilizers containing 19:19:19, N: P_2O_5 : K_2O are applied @ 7 g per sq. m to the growing beds after fumigation.

Two furrows 10 cm deep are made adjacent to the planting rows in the growing bed, the fertilizer mixture is applied and the furrows are closed. (ICAR, 2015) by adopting protected cultivation; productivity of vegetable crops can be increased by 3 to 5 times as compared to open environment (Bharadwaj *et al*., 2012)

Protected cultivation is an important agricultural sector showing constant growth and rapid expansion worldwide (Orgaz *et al*., 2005). Green house cucumbers supplied with correct quantity of fertilizers not only increases the yield but also improve the quality.

Application of major nutrients in proper ratio and required quantity can help growers to get the maximum out of these inputs (Kavitha *et al*., 2007) . Cucumbers are useful for people suffering from jaundice, constipation, and indigestion.

Cucumber is grown on an area of 2144 thousand hectares with a production of 80616 thousand metric tonnes and productivity of 37.6 metric tonnes per hectare in the world. In India, it is grown on an area of 74 thousand hectares with a production of 1142 thousand million tonnes and productivity of 15.02 tonnes per hectare (Anonymous, 2017).

Fertigation has emerged as an excellent method to improve the sustainability of greenhouse production by enabling better control over water and nutrient supply to the plants. Hence, drip irrigation under greenhouse cultivation is concentrated to supply irrigation water and fertilizers to rhizosphere through various phases of nutrient demand of a crop (Mostafa *et al*., 2014)

Lal and Kanaujia (2013) investigated that the higher net returns with B: C ratio of 1:8.16 is obtained with the application of 50% NPK + 50% FYM+ biofertilizer in cultivation capsicum cv. Chaudhary *et al*., (2007) stated that the application of increased levels of nitrogen upto 200 kg N/ha, significantly improved plant growth of capsicum. Biwalkar *et al*., (2015) and reported that different levels of fertigation and irrigation had significant effect on plant parameters, yield, WUE, FUE and quality parameters.

Hence, the present experiments were conducted to study the influence of fertigation and the source of nutrients on yield and B:C ratio of cultivation of capsicum and cucumber under protected cultivation.

2. Materials and Methods

Four field experiments were conducted using capsicum and cucumber as test crops during *kharif* of 2023 in two locations. Location 1 is situated at experimental farms of Regional Research stations, Paiyur, Krishnagiri district (12.2080° N, latitude, 78.0561° E longitude) and an elevation of 372 meters above mean sea level. Soil samples from the experimental locations were analysed for particle size distribution, water holding capacity (Piper, 1966) soil reaction and electrical conductivity in the 1:2.5 ratio soil : water suspension (Jackson, 1973), organic carbon (Walkley and Black 1934), Alkaline $KMnO_4$- N (Subbiah and Asija, 1956), Olsen-P (Olsen et al. 1956) and neutral normal NH_4OAc- K (Stanford and English, 1949).

The analytical results revealed that the experimental soil was well drained sandy loam sandy loam (pH 7.62 and electrical conductivity 0.032 dSm^{-1}) characterized by low organic carbon (0.40%), low available N (271 kg ha^{-1}) medium phosphorus (19.38 kg ha^{-1}) and potassium (198 kg ha^{-1}). The soil has available water holding capacity of 120 mm in one-meter soil depth.

Location 2 is situated at experimental farms of Regional Research stations, Paiyur, Krishnagiri district (12.5186173° N, latitude, 78.2137305 ° E longitude) and an elevation of 131 meters above mean sea level. The experimental soil was well drained sandy loam sandy loam (pH 7.86 and electrical conductivity 0.31 dSm^{-1}) characterized by medium organic carbon (0.60%), low available N (204 kg ha^{-1}) medium phosphorus (22.0 kg ha^{-1}) and high potassium (342 kg ha^{-1}). The soil has available water holding capacity of 150 mm in one-meter soil depth.

Both the experiments were laid out in randomized block design with five treatments and four replications. The treatments were imposed as per the treatment schedule. The experimental details along with the fertigaton schedule (Table 1 - 4) are detailed below. All the cultivation practices were followed for both the crops .

2.1 Experiment details

Crop: Capsicum**;** Hybrid: Inspiration (Spacing: 45 X 45 cm)

Treatments

T_1: 100 % Recommended dose of fertilizer (RDF) : 250:150:150 kg NPK ha^{-1}

T_2: 80 kg ha^{-1} WSF (19:19:19)

T_3: 120 kg ha^{-1} WSF (19:19:19)

T_4: 160 kg ha^{-1} WSF (19:19:19)

T_5: 200 kg ha^{-1} WSF (19:19:19)

Fertigation schedule for Capsicum

Crop stage	**Duration (days)**	**Fertilizer grade**	**Total Fertilizer (kg/ha)**	**Nutrient supplied**		
				N	**P**	**K**
Basal		DAP	250	45.4	115	0
Transplanting to plant Establishment stage	10	19:19:19	40	7.7	7.7	7.7
		13:0:45	40	5.2	0	18.2
		Urea	30	13.8	0	0
Vegetative stage	30	12:61:0	10	1.2	6.1	0
		19:19:19	40	7.7	7.7	7.7
		13:0:45	60	7.8	0	27.0
		CN	100	15.5	0	0

		Urea	40	18.4	0	0
Flower initiation to first picking	30	19:19:19	40	7.7	7.7	7.7
		13.0:45	80	10.3	0	36.3
		CN	200	31.0	0	0
		Urea	40	18.4	0	0
Harvesting stage	95	12:61:0	10	1.2	6.1	0
		13:0:45	100	13.0	0	45.0
		CN	200	31.0	0	0
		Urea	30	13.8	0	0
Total	165			249.1	150.3	149.6

Crop: Cucumber**;** Hybrid: Multistar (Spacing: 135 X 45 cm)

Treatments

T_1: 100 % Recommended dose of fertilizer (RDF) : 150:75:75 kg NPK ha^{-1}
T_2: 40 kg ha^{-1} WSF (19:19:19)
T_3: 60 kg ha^{-1} WSF (19:19:19)
T_4: 80 kg ha^{-1} WSF (19:19:19)
T_5: 100 kg ha^{-1} WSF (19:19:19)

Fertigation schedule for Cucumber

Crop stage	**Duration (days)**	**Fertilizer grade**	**Total Fertilizer (kg/ha)**	**Nutrient applied (kg/ha)**		
				N	**P**	**K**
Basal		DAP	125	22.5	57.6	0
Crop establishment stage	10	19:19:19	25	4.7	4.7	4.7
		Urea	30	13.8	-	-
Vegetative stage	20	12:61:0	10	1.2	6.1	-
		13:0:45	40	5.2	0	18
		CN	50	7.7		
		Urea	40	18.4	-	-
Flower initiation to first picking	20	19:19:19	25	4.7	4.7	4.7
		13:0:45	50	6.5	0	22.5
		CN	60	9.3		
		Urea	40	18.4	-	-

Harvesting stage	40	19:19:19	10	1.9	1.9	1.9
		13:0:45	50	6.5	0	22.5
		CN	60	9.3		
		Urea	45	20.7	-	-
Total				150.8	75.0	74.3

Fertilizer use efficiency was calculated by the formula

FUE (tons yield kgNPK^{-1}) = Economic yield (t ha^{-1}) / Total NPK applied (kg ha^{-1})
Agronomic efficiency was calculated by the formula

AE (tons yield kg WSF^{-1}) = Economic yield (t ha^{-1}) / WSF applied (kg ha^{-1})

3. Results and Discussion

3.1. Crop: Capsicum

3.1.1. Location I

Results of the yield and fertilizer use efficiency and agronomic efficiency of capsicum are given in Table 1. In capsicum, higher fruit yield of 87.1 t ha^{-1} was recorded in the treatment that received 200 kg WSF ha^{-1}. Significantly higher fruit yield was recorded in the treatment that received WSF @ 80, 120, 160, 200 kg ha^{-1} compared to the treatment that received 100% RDF as straight fertilizer.

The fertilizer use efficiency in capsicum was higher with lower levels of nutrients applied in the form of water soluble fertilizers (0.99 t fruit yield kg-NPK^{-1}) fertigation @ 80 kg WSF ha^{-1} compared to higher doses of nutrient application (Table 1).

But significant fruit yield (85.2 t ha^{-1}), net return (Rs. 30.45 lakhs ha^{-1}) and benefit cost ratio of 2.86 was registered in the treatment that received 120 kg WSF ha^{-1} (Table 2).

3.1.2 Location II

In Capsicum, higher fruit yield of 79.3 t ha^{-1} was recorded in the treatment that received 200 kg WSF ha^{-1}. Capsicum fruit yield of 77.2 t ha^{-1}, net return of 26.05 Lakh Rs. ha^{-1}) and benefit cost ratio of 2.59 was recorded in the treatment that received 120 kg WSF ha^{-1}. Significantly higher fruit yield was recorded in the treatment that received WSF @ 80, 120, 160, 200 kg ha^{-1} compared to the treatment that received 100% RDF as straight fertilizer. (Table 1) .

Table.1. Fruit yield of Capsicum, fertilizer use efficiency and agronomic efficiency

Treatments	Fruit yield (t/ha)			Fertilizer Use Efficiency (t yield kg-WSF $^{-1}$)			Agronomic Efficiency (t yield kg^{-1} WSF)		
	Loc. I	Loc. II	Mean	Loc. I	Loc. II	Mean	Loc. I	Loc. II	Mean
T1- 80 kg WSF ha^{-1}	78.8	70.2	74.5	0.99	0.88	0.93	0.32	0.31	0.32
T2 - 120 kg WSF ha^{-1}	85.2	77.2	81.2	0.71	0.64	0.68	0.27	0.27	0.27
T3 - 160 kg WSF ha^{-1}	85.8	77.5	81.7	0.54	0.48	0.51	0.20	0.20	0.20
T4 - 200 kg WSF ha^{-1}	87.1	79.3	83.2	0.44	0.40	0.42	0.17	0.17	0.17
T5 - 100% RDF (Soil application)	53.2	45.1	49.2	0.01	0.08	0.09	-	-	-
CD (0.05%)	2.12	2.46		-			-		

It is evident from the fruit yield data that though in least quantity of fertilizers applied plots yield does not commensurate with the reduced amount of water soluble fertilizers applied for the hybrid capsicum. These results corroborate with the findings of Singandhupe (2007)

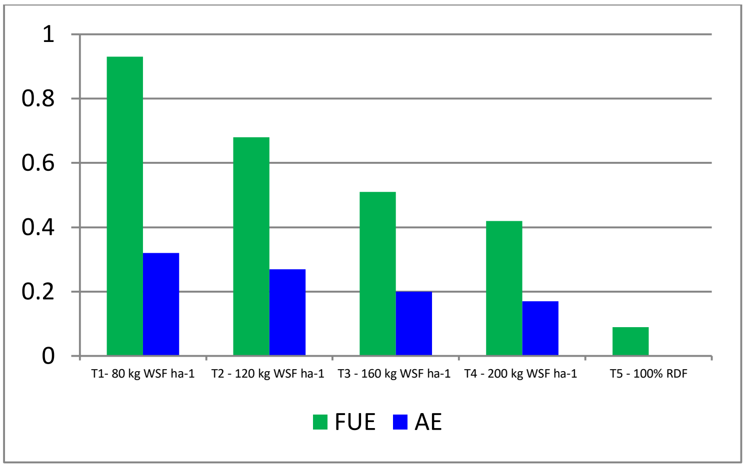

Fig.1 Fertilizer Use Efficiency (t yield kg-NPK^{-1}) and AE (t yield kg-NPK^{-1}) : Capsicum

Nutrient use efficiency (NUE) is a critically important concept in the evaluation of crop production systems. It can be greatly impacted by fertilizer management as well as by soil- and plant-water management. Veeranna et al., (2000) reported that decreasing fertilizer level by 20 per cent than the recommended level especially under fertigation may not affect the yield level in chilli because of improved fertilizer use efficiency. Fertilizer saving to the extent of 70 per cent respectively with comparable yield levels was possible under the trickle fertigated crop as compared to the furrow irrigated crop of potatoes.

Higher use efficiency of nutrients under fertigation might be ascribed to increase the availability of nutrients to the plants directly near the root zone but, lower nutrient use efficiency in soil application of fertilizers might be due to reduced nutrient uptake associated with reduced moisture availability and less solubility of nutrients. Similar results were observed by Gururaj (2013) and Anusha (2015)

Net return of 27.05 Lakh Rs. ha^{-1} and benefit cost ratio of 2.63 was registered in the treatment that received 200 kg WSF ha^{-1}(Table 4). Sreenivasa et al. (2009) reported that the benefit cost ratio for capsicum cultivation in polyhouse was 1.80. Similar results were found by Sreedhara et al. (2013) and Kumar (2016) in capsicum cultivation and Nikki et al. (2017) in bell paper cultivation.

Table. 2. Economics of fertigation of water soluble fertilizers

Treatments	**Cost of fertigation (Lakh Rs./ha)**	**Cost of cultivation (Lakh Rs./ha)**	**Gross return (Lakh Rs./ha)**		**Net return (Lakh Rs./ha)**		**BC Ratio**	
			Loc. I	**Loc. II**	**Loc. I**	**Loc. II**	**Loc. I**	**Loc. II**
T1- 80 kg WSF ha^{-1}	13.26	16.33	43.34	38.61	27.01	22.28	2.65	2.36
T2 - 120 kg WSF ha^{-1}	14.06	16.41	46.86	42.46	30.45	26.05	2.86	2.59
T3 - 160 kg WSF ha^{-1}	14.85	16.49	47.19	42.63	30.70	26.14	2.86	2.59
T4 - 200 kg WSF ha^{-1}	15.66	16.56	47.90	43.62	31.34	27.05	2.89	2.63
T5 - 100% RDF	0.258	15.25	29.26	24.81	14.00	23.28	1.92	1.63

3.2. Crop: Cucumber

3.2.1 Location I

In Cucumber, maximum fruit yield of 75.0 t ha^{-1} was recorded in the treatment that received 100 kg WSF ha^{-1} (Table 3). Significantly higher fruit yield (73.9 t ha^{-1}), net return (8.17 Lakh Rs.ha^{-1}) and benefit cost ratio of 2.23 was recorded in the treatment that received 60 kg WSF ha^{-1} (Table 4). Significantly higher fruit yield was recorded in the treatment that received WSF @ 40, 60, 80, 100 kg ha^{-1} compared to the treatment that received 100% RDF as straight fertilizer.

3.2.2. Location II

In Cucumber, maximum fruit yield of 73.3 t ha^{-1} was recorded in the treatment that received 100 kg WSF ha^{-1}(Table 3). Fruit yield (72.3 t ha^{-1}), net return (Lakh Rs. 7.85 ha^{-1}) and benefit cost ratio of 2.18 was registered in the treatment that received 60 kg WSF ha^{-1}(Table 4). Significantly higher fruit yield was recorded in the treatment that received WSF @ 40, 60, 80, 100 kg ha^{-1} compared to the treatment that received 100% RDF as straight fertilizer.

Table. 3. Fruit yield of Cucumber, fertilizer use efficiency and agronomic efficiency

Treatments	Fruit yield (t/ha)		Fertilizer Use Efficiency (t yield kg-NPK^{-1})			Agronomic Efficiency (t yield kg-WSF^{-1})		
	Loc. I	Loc. II	Loc. I	Loc. II	Mean	Loc. I	Loc. II	Mean
T1 - 40 kg WSF ha^{-1}	67.4	65.8	1.69	1.65	1.67	0.45	0.43	0.44
T2 - 60 kg WSF ha^{-1}	73.9	72.3	1.23	1.21	1.22	0.41	0.40	0.41
T3 - 80 kg WSF ha^{-1}	74.1	72.5	0.93	0.91	0.92	0.30	0.30	0.30
T4 - 100 kg WSF ha^{-1}	75.0	73.3	0.75	0.73	0.74	0.26	0.25	0.26
T5 - 100% RDF	49.5	48.5	0.165	0.16	0.16	-	-	-
CD (0.05%)	2.32	3.07	-	-		-	-	-

Patil and Gadge (2016) recorded maximum yield of cucumber under fertigation with 125% RDF in shade net house. Fertigation ensures saving in fertilizer (40-60%), due to “better fertilizer use efficiency “and “reduction in leaching” (Kumar and Singh 2002).

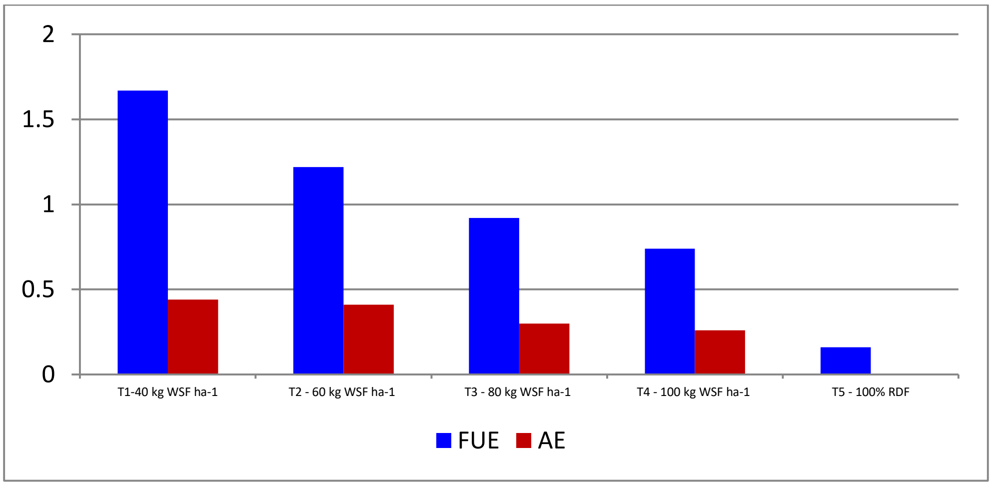

Fig.2 Fertilizer Use Efficiency (t yield kg-NPK^{-1}) and AE (t yield kg-NPK^{-1}) : Cucumber

The enhanced supply of nutrients through increased fertigation level in the root vicinity of plant maintain optimum nutrient concentration in the root zone throughout the crop growth period, which increases the uptake of moisture and nutrients resulted in increasing all the growth attributes of cucumber which increases the photosynthetic rate and absorbed APAR resulted in more translocation of photosynthates towards reproductive organ (sink) which ultimately increases the yield attributes of cucumber. Janapriya et al. (2010) also reported that significantly higher yield and yield attributes under increased fertigation level. Similar results are also reported by Sharma et al. (2009), Dai et al. (2011) and Zhang et al. (2011)

Table.4 Effect of fertigation of water soluble fertilizers on economics of Cucumber

Treatments	**Cost of fertigation (Lakh Rs./ha)**	**Cost of cultivation (Lakh Rs./ha)**	**Gross return (Lakh Rs./ha)**		**Net return (Lakh Rs./ha)**		**BC Ratio**	
			Loc. I	**Loc. II**	**Loc. I**	**Loc. II**	**Loc. I**	**Loc. II**
T1 - 40 kg WSF ha^{-1}	0.574	6.57	13.49	13.18	6.91	6.59	2.05	2.00
T2 - 60 kg WSF ha^{-1}	0.614	6.61	14.78	14.47	8.17	7.85	2.23	2.18
T3 - 80 kg WSF ha^{-1}	0.654	6.65	14.82	14.51	8.17	7.85	2.23	2.18
T4 - 100 kg WSF ha^{-1}	0.694	6.69	15.00	14.67	8.31	7.97	2.24	2.19
T5 - 100% RDF	1.330	6.13	9.90	9.70	3.77	3.57	1.61	1.58
CD (0.05%)	-	-	-	-	-	-	-	-

Janapriya et al. (2010) also reported that significantly higher yield and yield attributes under increased fertigation level. Similar results are also reported by Sharma et al. (2009), Dai et al. (2011) and Zhang et al. (2011)

Fertigation saves fertilizer nutrients since fertilizer is applied in splits according to the demand of the crop. An improved availability of moisture, nutrients, and uniform distribution of fertigated nutrients in the crop root zone throughout the growth stages leading to better uptake of nutrients.

Ramachandrappa et al. (2010) also recorded higher fertilizer use efficiency at 75% recommended dose of NPK through fertigation than 100% recommended NPK fertigation in green chilli. Gireesh et al. (2020) and Suman Kumari et al. (2020) also reported maximum net returns and cost: benefit ratio with the application of 100% recommended dose of NPK through fertigation.

Kumar (2015) and Sanjeev et al. (2015) reported maximum net returns in cucumber cultivation under protected cultivation of cucumber.

From the present study it can be concluded that the fertigation under protected cultivation with capsicum and cucumber fetched higher yield and higher income. Fertigation with water soluble fertilizer @ 120 kg ha^{-1} and 60 kg ha^{-1} registered significantly higher fruit yield, net return and Benefit Cost ratio in capsicum and cucumber respectively. Fertilizer use efficiency (FUE) of 0.93 t fruit yield kg^{-1} WSF and Agronomic efficiency (AE) of 0.32 t fruit yield kg^{-1} WSF were registered to be maximum due to the fertigation of 80 kg WSF ha^{-1} in capsicum cultivation . While in cucumber cultivation fertigation of 40 kg WSF ha^{-1} recorded maximum FUE of 0.93 t fruit yield kg^{-1} WSF and AE of 0.32 t fruit yield kg^{-1} WSF. Benefit : Cost ratio were acquired in capsicum (2.89) and cucumber (2.24) due to the fertigation of water soluble fertilizers under protected cultivation.

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