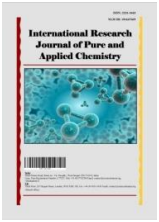

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Effect of Fertigation on Yield, Fertilizer Use Efficiency and Economics in Hybrid Ridge Gourd

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Authors' contributions

This work was carried out in collaboration among all authors. Author HCAM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AKN and DK managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A field Investigation was carried out to study the effect of fertigation on yield, fertilizer use efficiency and economics of hybrid ridge gourd [*Luffa acutangula* (L.) Roxb] Arka Vikram during 2018-2019 at Vegetable Research Block of ICAR- Indian Institute of Horticultural Research, Bengaluru, Karnataka. The experiment was laid out in randomized complete block design having eight treatments and three replications. The results of the experiment revealed that the treatment T_3 *i.e* application of water soluble fertilizers @ 150:90:150 kg NPK ha^{-1} through fertigation recorded maximum number of female flower per vine (29.73), number of fruits per vine (19.68), fruit length (49.76 cm), fruit girth (18.40 cm), average fruit weight (454.03 g), fruit yield per vine (4.03 kg) and fruit yield per hectare (53.73 t). Application of water soluble fertilizers @ 150:90:150 kg NPK ha^{-1} through fertigation (T_3) recorded significantly higher fruit yield per hectare (53.73 t ha^{-1}), which was higher to the tune of 23.8 to 70.4 per cent than other treatments tested in hybrid ridge gourd. The second highest fruit yield was obtained with T_2 (43.40 t ha^{-1}) followed by T_1 (42.10 t ha^{-1}). However,

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T_5 *i.e* application of water soluble fertilizers @ 50:30:50 kg NPK ha^{-1} resulted in highest fertilizer use efficiency (245.38 kg yield kg-NPK^{-1}) compared to other treatments. Fertigation at 100% NPK dose along with mulching with silver-black plastic mulch gave the highest net income (Rs.555435.0 ha^{-1}) and B: C ratio of 2.22.

Keywords: Ridge gourd; fertigation; water soluble fertilizers; yield and attributing characters; fertilizer use efficiency and economics.

1. INTRODUCTION

Ridge gourd [L*uffa acutangula* (L.) Roxb.], popularly known as angled gourd, Chinese okra, ribbed gourd and Kalitori. This crop belongs to genus *Luffa of "*Cucurbitaceae" family. Ridge gourd is known to have originated in India and is cultivated in the tropics and sub-tropics for its tender edible fruits both on commercial scale and in kitchen gardens throughout the country and in some other parts of the world. The tender fruits are green in colour, which are used in various food preparations/culinary items. The fruit contains a gelatinous compound "luffein" which is traditionally used for the treatment of stomach ailment and fever [1]. India ranks second among the vegetable producing countries of the world and produced 187.47 million tonnes of vegetables from an area of 10.4 million hectares in 2017-2018 [2]. The country may require 225 million tones of vegetables by 2020-21 to feed its ever growing population. It necessitates increasing the production of vegetables by adopting improved technologies and high yielding varieties [3]. The statistical data on most of the cucurbitaceous vegetables with respect to area and production are not available, however squashes and gourds as a group of vegetables has been estimated to occupy an area of 3,632 hectares in Karnataka with a production of 34,683 tonnes and productivity of 9.54 tonnes per hectare [4].

Balanced nutrition is one of the important factor affecting the growth and productivity of vegetable crops. Precise management of irrigation quantity along with the rate and timing of nutrient application are of critical importance to obtain desired results in terms of productivity and nutrient use efficiency (NUE). The fertigation allows application of right amounts of plant nutrients uniformly to the wetted root volume zone where most of the active roots are concentrated and this helps in enhancing nutrient use efficiency. It has been found to improve the productivity and quality of crop produce along with improved resource use efficiency [5]. Excessive use of fertilizers for increasing the crop yields will lead to nutrient leaching which ultimately affects the soil and environmental health besides increasing cost of production [6]. The other issue related to drip irrigation and fertigation is its economic viability and the farmers are often reluctant to adopt this method due to their weak resource base. Scientific information on fertigation especially on ridge gourd is very less; hence, the present study was conducted to find out the optimum fertigation doses and economic viability of the system for yield and yield attributing characters of Ridge gourd hybrid Arka Vikram.

2. MATERIALS AND METHODS

The field experiment was conducted at the Vegetable Research Block of ICAR-Indian Institute of Horticultural Research, Hessarghatta, Bengaluru, during 2018-2019 (September 2018 to February 2019) which is situated at 890 meters above mean sea level and has the benefit of receiving both South West and North East monsoons. The normal rainfall of this area is about 800 mm, distributed over a period of six to seven months (May-November) with peaks during September. The type of the experimental site was well drained red sandy loam soil having initial organic carbon (1.06%), pH (6.75), electrical conductivity (0.23 dSm^{-1}), available nitrogen (171.92 kg ha^{-1}), available phosphorus (34.69 kg ha^{-1}) and available potassium (217.29 kg ha^{-1}). The 16 days old seedlings of ridge gourd hybrid "Arka Vikram" were transplanted at 1.50 x 0.50 m spacing during the first week of October 2018. Ridge gourd hybrid "Arka Vikram" has the character of early flowering. The first female flower appearance takes place at 40 days and 46 days for first picking of fruits. It produces green, long and tender fruits, which has excellent cooking quality, nutritionally rich in antioxidant activity and minerals. It yields around 34.0 t ha^{-1} in 120-135 days duration. The experiment was laid out in randomized complete block design with eight treatments, which was replicated thrice. The farm yard manure @ 25 tonnes and neem cake @ 625 kg ha^{-1} was applied uniformly to all the treatments. The treatment details and

the amount of fertilizers applied treatment wise are given in Table 1. The fertilizers were applied based on fertigation treatments in the form of water soluble fertilizers (urea, 19:19:19 and potassium nitrate) and conventional fertilizers (urea, di-ammonium phosphate and muriate of potash). For soil application treatment, conventional fertilizers *viz.,* urea, single super phosphate and muriate of potash were applied, where, entire P and half of N and K were given as basal and remaining half of N and K was side dressed at 30^{th} and 60^{th} days after transplanting in equal splits. In other treatments, fertigation was started two weeks after transplanting and given at weekly interval. Yield parameters like number of female flowers per vine, number of fruits per vine and fruit yield per vine were recorded from five plants selected randomly replication wise in all the treatments. The five randomly selected fruits were weighed for their mean weight and also for fruit length and girth. All the agronomic and plant protection measures were adopted as per the recommended package of practices [7].

2.1 Fertilizer Use Efficiency

Fertilizer use efficiency (FUE) 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. Fertilizer use efficiency of ridge gourd was calculated by using the following formula.

FUE (kg yield kg-NPK^{-1}) = Economic yield (kg ha^{-1}) / Total NPK applied (kg ha^{-1})

2.2 Economics

The cost of cultivation for each treatment was calculated based on the inputs used during the conduct of experiment. The prices of all the inputs and the labor cost that were prevailing at the time of their use were considered to work out the cost of cultivation. Gross return was calculated from the market price of ridge gourd during the experiment period. Net income was estimated by deducting total cost of cultivation in each treatment from the respective gross returns.

2.3 Benefit: Cost Ratio

The benefit cost ratio was worked out by using the following formula.

B: C ratio: Net income (Rs. ha^{-1}) / Cost of cultivation (Rs. ha^{-1})

2.4 Statistical Analysis

The data obtained from field experiment relating to different characters were subjected to statistical analysis by applying the technique of analysis of variance (ANOVA) as described by Panse [8]. In cases where F values were found significant, critical differences (CD) were calculated at five per cent probability level. OP stat is used for statistical analysis.

Table 1. Treatment details and amount of fertilizers applied under different treatments (kg ha^{-1})

Treatment	Urea	19 all	KNO_3	SSP	DAP	MOP
T_1 : Fertigation with water soluble fertilizers @ 100:60:100 kg NPK ha^{-1}	62.00	316.00	89.00	-	-	-
T_2 : Fertigation with water soluble fertilizers @ 125:75:125 kg NPK ha^{-1}	77.50	395.00	111.25	-	-	-
T_3 : Fertigation with water soluble fertilizers @ 150:90:150 kg NPK ha^{-1}	93.00	474.00	133.50	-	-	-
T_4 : Fertigation with water soluble fertilizers @ 75:45:75 kg NPK ha^{-1}	47.00	237.00	66.75	-	-	-
T_5 : Fertigation with water soluble fertilizers @ 50:30:50 kg NPK ha^{-1}	31.00	158.00	44.50	-	-	-
T_6 : Fertigation with water soluble fertilizers @ 50:50:50 kg NPK ha^{-1}	-	263.00	-	-	-	-
T_7 : Fertigation with normal fertilizers @ 100:60:100 kg NPK ha^{-1}	166.20	-	-		130.00	167.00
T_8 : Soil application of NPK fertilizers @ 100:60:100 kg NPK ha^{-1}	217.00	-	-	375.00	-	167.00

19 all: 19:19:19; KNO_3: Potassium Nitrate; SSP : Single Super Phosphate; DAP : Di- Ammonium Phosphate; MOP : Muriate of Potash

3. RESULTS AND DISCUSSION

3.1 Yield and Yield Attributing Characters

Yield and yield attributing characters of ridge gourd hybrid Arka Vikram were significantly influenced by different treatments and data are presented in Table 2. Significantly (5%) higher number of female flowers per vine at 90 days after transplanting (29.73) was recorded in treatment T_3 which received water soluble fertilizers *i.e.* Urea, 19:19:19 and KNO_3 @ 150:90:150 kg NPK ha^{-1}, whereas the treatment T_5 *i.e.* fertigation with WSF at 50:30:50 kg NPK ha^{-1} recorded minimum number of female flowers per vine (20.67). This might be due to application of optimum and balanced dose of nitrogen, phosphorus and potassium by fertigation which helped to increase the number of female flowers per vine. Similar findings were also obtained by Shinde [9] in cucumber and Rani [10] in pointed gourd. At higher fertigation level better availability of sufficient quantity of nutrients especially the applied higher dosage of potassium given to the plants in the water soluble form may also have increased the number of female flowers per vine. Similar results were also recorded by Manohar [11], Sharma [12] and Kumar [13] in ridge gourd and Nayak [14] in pointed gourd.

Application of water soluble fertilizers @ 150:90:150 kg NPK ha^{-1} through fertigation (T_3) recorded higher number of fruits (19.68) per vine than other treatments. The second highest (16.55) and lowest (13.90) number of fruits per vine was recorded in T_2 and T_5 respectively. The increase in number of fruits might be due to increase in number of female flowers on account of increased number of primary and secondary branches either due to increased nitrogen or potash. Similar findings were also obtained by Shinde [9] and Parmar [15] in cucumber, Rani [10] and Nayak [14] in pointed gourd and Anil Kumar [3] in ridge gourd. Similarly, significantly longer fruits were also recorded with T_3 (49.76 cm), which remained on par with T_8 (49.11 cm) and T_2 (47.23 cm) only. Fruit girth was significantly higher with T_2 (20.05 cm), *i.e.* application of 100:60:100 kg NPK ha^{-1} using water soluble fertilizers through fertigation than other treatments. The shortest and thinnest fruits were recorded with T_6 (42.06 cm) and T_4 (16.69 cm). Increased nutrition to the vines with increase in levels of nitrogen and increased synthesis of chlorophyll and amino acids helped in efficient uptake resulting in increased length of the fruits. Similar findings were reported by Rodriguez [16] in musk melon, Sharma [12] in cucumber, Rasul [17] in kakrol and Anil Kumar [3] in ridge gourd. The mean fruit weight was maximum with T_3 (454.03 g), followed by T_2 (431.42 g), T_1 (422.17 g) and T_8 (408.69 g). This may be due to the increase in fruit length and girth and also due to increased nutrition to the vines with increase in levels of nitrogen and increased synthesis of chlorophyll and amino acids. Similar differences in fruit size in kakrol strains/cultivars were also reported by Rasul [17] The lowest mean fruit weight was recorded in T_5 (348.87 g).

Fruit yield per vine was significantly higher in T_3 (4.03 kg) than all other treatments. The second highest value for the fruit yield per vine was recorded with T_2 (3.26 kg). The higher level of fertigation, which had made the plants to respond in production of higher flowers per plant and percent of fruit set again, has helped in obtaining the highest fruit yield per plant. This is similar to the results reported by Papadopoulos [18],

Table 2. Effect of fertigation treatments on yield and yield attributes in hybrid ridge gourd

Treatments	Number of female flowers per vine	Number of fruits per vine	Fruit length (cm)	Fruit girth (cm)	Mean fruit weight (g)	Fruit yield per vine (kg)	Fruit yield (t ha^{-1})
T_1	25.80	15.47	44.38	17.72	422.17	3.06	42.10
T_2	26.60	16.55	47.23	20.05	431.42	3.26	43.40
T_3	29.73	19.68	49.76	18.40	454.03	4.03	53.73
T_4	23.93	15.17	42.97	16.69	363.57	3.09	40.80
T_5	20.67	13.90	44.56	18.17	348.87	2.40	31.90
T_6	22.53	14.95	42.06	16.81	360.55	2.69	35.80
T_7	22.13	14.37	44.83	17.68	373.21	2.56	34.10
T_8	25.40	16.20	49.11	18.03	408.69	3.16	36.50
S.Em±	1.26	0.77	0.85	0.48	22.55	0.16	0.61
C.D @ 5%	3.88	2.37	2.62	1.49	69.06	0.49	1.88

Table 3. Effect of fertigation treatments on cost economics (ha-1) for the hybrid ridge gourd

Treatments	Fruit yield (t ha^{-1})	FUE (kg yield kg-NPK^{-1})	Total cost of cultivation (Rs ha^{-1})	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	B:C ratio
T_1	42.10	162.00	233961	631500	397539	1.70
T_2	43.40	133.53	242193	651000	408807	1.69
T_3	53.73	133.77	250515	805950	555435	2.22
T_4	40.80	209.23	225732	612000	386268	1.71
T_5	31.90	245.38	217452	478500	261048	1.20
T_6	35.80	238.67	224613	537000	312387	1.39
T_7	34.10	131.15	207036	511500	304464	1.47
T_8	36.50	140.38	206906	547500	340594	1.65

Choudhari [19], Manohar [11] and Sharma (2009) [12] in different crops. Application of water soluble fertilizers @ 150:90:150 kg NPK ha^{-1} through fertigation (T_3) recorded significantly highest fruit yield per hectare (53.73 t ha^{-1}), which was higher to the tune of 23.8 to 70.4 per cent than other treatments tested in hybrid ridge gourd. The second highest fruit yield was obtained with T_2 (43.40 t ha^{-1}) followed by T_1 (42.10 t ha^{-1}). It is evident from the data that application of lower amount of water soluble fertilizers through fertigation reduced the yield substantially (31.90 to 35.80 t ha^{-1}) compared to the best treatment (150:90:150 kg NPK ha^{-1} through fertigation). Application of water soluble fertilizers @ 50:30:50 kg NPK ha^{-1} resulted in lowest fruit yield of 31.90 t $ha^{-1.}$

The highest fruit yield per hectare and increase in yield in treatment T_3 might have been due to the better performance of yield attributes as these traits have positive influence on the yield. The results on yield were in conformity with those of Wang [20] in watermelon, Rani [10] and Ram [21] in pointed gourd, Kayande [22] in bitter gourd, Sikarwar [23] in cucumber and Anil Kumar [3] in ridge gourd.

3.2 Fertilizer Use Efficiency

The fertilizer use efficiency in hybrid ridge gourd was higher with lower levels of nutrients applied in the form of water soluble fertilizers *i.e.* T_5 (245.38 kg yield kg-NPK^{-1}) fertigation with WSF @ 50:30:50 kg NPK ha^{-1} and T_6 (238.67 kg yield kg-NPK^{-1}*) i.e.* fertigation with WSF @ 50:50:50 kg NPK ha^{-1} compared to higher doses of nutrient application (Table 3). It is evident from the fruit yield data that though T_5 received the least quantity of fertilizers *i.e.* almost three times less than the maximum quantity (T_3), but yield does not commensurate with the reduced amount of water soluble fertilizers applied. These results corroborate with the findings of Singandhupe [24].

3.3 Economic Analysis

Application of higher amount of water soluble fertilizers through fertigation increased the production of hybrid ridge gourd (Table 3). Among the treatment combinations the treatment T_3 *i.e*. fertigation with WSF @ 150:90:150 kg NPK ha^{-1} recorded the highest benefit cost ratio (2.22) with gross income (Rs.8,05,950), net income (Rs.5,55,435) followed by T_4 *i.e.* fertigation with WSF @ 75:45:75 kg NPK ha^{-1}, where it recorded the benefit cost ratio of 1.71. The lowest was recorded in the treatment T_5 (gross income - Rs.4,78,500, net income - Rs.2,61,048 and benefit-cost ratio - 1.20). Higher net income and benefit cost ratio was obtained in T_3 attributing to most of the yield attributing characters and finally highest fruit yield in hybrid ridge gourd. Shinde et al*.,* (2010) also recorded highest net return and benefit cost ratio (2.22) with 100 per cent recommended dose of fertilizer under fertigation in cucumber. Mangal Patil [25] also recorded higher gross return (Rs.125.2 m^{-2}), net return (Rs. 51.28 m^{-2}) and benefit-cost ratio (1.69) in shade net grown cucumber.

4. CONCLUSION

That application of higher amount of water soluble fertilizers through fertigation produced highest fruit yields. Fertigation with water soluble fertilizer *i.e*. Urea, 19:19:19 and KNO_3 @ 150:90:150 kg NPK ha^{-1} resulted in higher yield attributing values and yield (53.73 t ha^{-1}). Though this resulted in lower fertilizer use efficiency (133.77 kg yield kg-NPK^{-1}) compared to other treatments, where lesser amount of fertilizers were applied, but it was found beneficial in obtaining higher gross income (Rs.8,05,950 ha^{-1})

and net returns (Rs.5,55,435 ha^{-1}) and benefit-cost ratio (2.22).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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