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Effect of mulching and fertigation on growth yield and quality of French bean (*Phaseolus vulgaris* L.)

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Abstract
A field experiment was conducted to evaluate the effect of mulching and fertigation on growth, yield and quality of french bean (*Phaseolus vulgaris* L.).The experiment consisted of four main plots i.e., different levels of fertigation and three sub plotsi. e., mulching with paddy straw, mulching with plastic polythene and no mulch. The experiment was conducted in split plot design and it was replicated thrice. Mulching with polythene and 100 per cent RDF through fertigation recorded maximum plant height (51.55 cm), number of primary branches (6.64), Leaf area (564.54 cm^2), leaf area index (1.06), number of pods per cluster (10.02), number of clusters per plant (7.41), yield per plant (80.94g), yield per hectare (11.58 t ha^{-1}), nitrogen uptake (92.30 kg ha^{-1}), phosphorous uptake (9.25 kg ha^{-1}), potassium uptake (80.91 kg ha^{-1}),nitrogen use efficiency (178.35 kg pods per kg of nitrogen), phosphorous use efficiency (106.30 kg pods per kg of phosphorous), potassium use efficiency (144.12 kg pods per kg of potassium), and water use efficiency (504.02 kg ha^{-1} cm^{-1}). Higher shelf life (8.05%), higher moisture content (89.05%),higher firmness (4.05 kg/cm^2) and higher crude fibre content(16.19%)in the pods were recorded where mulching was applied along with 100 per cent RDF through fertigation compared to other treatments.

Keywords: Fertigation, plastic mulch, clusters, nutrient use efficiency, water use efficiency

Introduction
French bean (*Phaseolus vulgaris* L.) is one of the most important leguminous vegetable. It is also known as common bean, bush bean, kidney bean, snap bean, haricot bean and navy bean. It is grown for the tender green beans as well as dry beans seeds (Rajmah). It is originated in warm temperate region of Central America (Mexico and Guatemala) and Southern America, mainly the Andean regions. The vitamins A and C present in green beans are an excellent antioxidant that reduces the amount of free radicals in the body and prevents the build up of plaque in arteries and veins. The green pods are rich source of proteins, minerals and vitamins (Punia*et al*., 2008) [26]. Beans are often the main source of protein, and a significant source of minerals for low- income population (Laparra *et al*., 2009) [18].
Fertigation has immense utility in increasing the production of french bean. In the past, some efforts have been made to study the influence of fertigation on vegetative and reproductive parameters of french bean. The fertigation with water soluble fertilizers (WSF) is superior over normal fertilizers with respect to growth, yield and quality of pole beans. Fertigation supplies adequate water and nutrients, maintains precise time and ensures uniform distribution of nutrients to meet the crop nutrient demand. Further, fertigation saves substantial amount of fertilizer through reduced leaching losses (Kumar *et al*., 2016) [13].
The increased crop productivity under mulching system is mainly attributed to factors like (i) reduction in soil evaporation (ii) increase in storage of water in the soil, (iii) increase in soil temperature and (iv) increase in the activity of soil nutrients (Jiang *et al*., 2018) [11]. Mulching is an appropriate approach to conserve moisture besides improving crop yield. Reduction in evaporation from crop field through polythene mulch enhances both productivity and WUE by creating a barrier between soil surface and adjacent atmosphere. Mulching minimizes the evaporation loss from soil surface and thus utilizes the conserved moisture for higher transpiration, improves yield and WUE of crop (Agele*et al*., 2002) [2]. Plastic mulching has become a globally applied agricultural practice for its instant economic benefits such as higher yields, earlier harvests, improved fruit quality and increased water-use efficiency (Mohammed Ali,2009) [20]. Soil mulching not only reduces the soil evaporation and weed growth but also improves the aerial environment around the plants which facilitate plant growth and yield. Use of mulches for early crop offers great scope in such a situation because of conserving moisture

and improving soil temperature (Singh and Kamal, 2012) [30] The fertigation and mulching has beneficial impact on the yield of vegetable crops. Hence, there is a need to assess the performance of this commercial vegetable crop using different fertigation levels and different mulches. Hence this study was undertaken.

Material and Methods

The experiment was conducted during 2020 and 2021 in the fields of All India Coordinated Research Project on (PEASEM), at College of Agriculture Engineering, University of Agricultural Sciences, Raichur. The climate of the experimental location is semiarid and average annual rainfall is 722 mm. The elevation of experimental field is 406 m above mean sea level (MSL). French bean variety ArkaArjun used in the experiment was procured from Indian Institute of Horticulture Research, Bengaluru. This experiment was laid out in split plot design with twelve treatments and three replications. The treatments consisted of main plot treatments i.e., F_1-50% of RDF through fertigation, F_2-75% of RDF through fertigation, F_3-100% of RDF through fertigation and F_4-100% RDF as soil application and sub plot treatments i.e., M_1- mulching with paddy straw, M_2- mulching with plastic polythene mulch and M_3- no mulch. Fertigation was provided to the treatment plots as per the experimental plan at weekly interval. The land was thoroughly ploughed and brought to a fine tilth. Raised beds of 10m length and 1m width were prepared. Drip laterals of 4 lph were placed on the beds and the beds were covered with the mulching material as per the treatment plan. Where ever plastic mulches were used holes were made and french bean seeds were sown at the required spacing of 45 x 15 cm. Irrigation and fertigation was provided as per the plan of the experiment. The required nitrogen, phosphorous and potassium was applied to the experimental plot through water soluble fertilizers (WSF) i.e. 19:19:19 and 00:52:34. Fertilizers were applied by pressure differential method by using venturi system. The required pressure was monitored by using pressure gauge fitted on the supply line just after the filter. The observations were recorded on five randomly selected plants from each treatment. Growth parameters were recorded at 15 days, 30 days, 45 days and 60 days after sowing. The yield parameters were recorded as and when harvesting was done. Analysis of variance was performed following the statistical method described by *Panse and Sukhatme (1967*) [24] and significance of differences among treatment means were calculated at 5% level of significance.

Results and Discussion

This experiment was conducted for two years and the pooled data is presented in Table 1to Table 4 and the results are discussed as follows.

Fertigation and mulching had a non- significant influence on plant height but had significant influence on number of primary branches, leaf area and leaf area index (Table 1). However, fertigation with 100% RDF exhibited higher values for plant height (50.88 cm), number of primary branches (6.33), leaf area (533.61 cm^2) and leaf area index (0.97) when compared to other levels of fertigation and application of 100% RDF through soil application. As far as the mulching is concerned, plastic polythene mulch produced higher plant height (48.51 cm), number of primary branches (5.84), leaf area (480.74 cm^2) and leaf area index (0.83), when compared to paddy straw mulch and no mulch. When interactions were noticed, it was found that 100% RDF through fertigation and plastic polythene mulch produced maximum plant height (51.55 cm), number of primary branches (6.64), leaf area (564.54 cm^2) and leaf area Index (1.06). Higher plant height, number of branches, leaf area and leaf area index with application of 100% RDF through fertigation might be due to better availability of nutrients in soluble form at the root zone of the plant. The growth of plants are propelled by nitrogen and phosphorous as nitrogen is an important constituent of protoplasm, cell nucleus, amino acids and chlorophll (Godara *et al*,, 2013). Luxurientavailability of nutrients at the root zone of the plants due to fertigation might have contributed for higher growth parameters. These results are in confirmation with Bansod (2007) [8], Chethan and Singh (2009) [30], Bhasker*et al*. (2018) [7] and Gosai*et al*. (2018) [10]. The plastic mulch and 100% RDF fertigation invariably performed well among all the main and sub-treatments levels. The interaction between the plastic mulch and 100% RDF fertigation resulted in highest plant growth parameters at all the growth stages of the crop compared to straw mulch and control treatments. The better hydrothermal conditions in plastic mulched treatments might have encouraged good growth and this could be the reason for higher growth parameters. Also, increased level of nutrient application would have helped in better protein synthesis and building up of plant metabolites that might have lead to taller plants with wider leaves and more number of leaves (Kukade *et al*. 2015 and Fekry, 2017) [14, 15].

There was a significant influence of fertigation and mulching on number of pods per cluster, number of clusters per plant, yield per plant and yield per hectare (Table 2), fertigation with 100% RDF exhibited higher number of pods per cluster (9.76), number of clusters per plant (7.14), yield per plant (77.68 g) and yield per hectare (9.57 t ha^{-1}) when compared to other levels of fertigation and application of 100% RDF through soil application. As far as the mulching is concerned, plastic polythene mulch produced higher number of pods per cluster (9.15), number of clusters per plant (6.40), yield per plant (79.24 g) and yield per hectare (10.52 t ha^{-1}) when compared to paddy straw mulch and no mulch. When interactions were observed, it was found that 100% RDF through fertigation and plastic polythene mulch produced maximum number of pods per cluster (10.02), number of clusters per plant (7.41), yield per plant (80.94 g) and yield per hectare (11.58 t ha^{-1}) This can be attributed to better microclimatic conditions provided by plastic mulch and fertigation collectively. The use of drip irrigation and mulching promoted the growth of onion over control as reported by studies conducted by Jamil*et al*., 2005 [17], Inusah*et al*., 2013 [17], Lakew*et al*., 2014 [19], Job *et al*., 2016 [27], Prasad *et al*., 2017 [25] and Rachel *et al*., 2018(21).Growth and yield parameters exhibited higher values when plastic mulches were used and fertigation of 100% RDF was provided. The interaction of these two components also produced higher growth and yield (Anjitha, 2020) [1].

Fertigation and mulching had significant influence on the uptake of nitrogen phosphorus and potassium (Table 3). The uptake of nitrogen phosphorus and potassium was maximum (88.03 kg ha^{-1} 8.91 kg ha^{-1} and 78.88 kg ha^{-1},respectively) in fertigation with 100% RDF when compared to other levels of fertigation and application of 100% RDF through soil application. As far as the mulching is concerned, plastic polythene mulch resulted in higher uptake of nitrogen (78.01 kg ha^{-1}) phosphorus (8.87 kg ha^{-1}) and potassium (77.94 kg ha^{-1}) when compared to paddy straw mulch and no mulch. When interactions were observed, it was found that the uptake of nitrogen, phosphorus and potassium was higher (88.03 kg ha^{-1}, 8.91 kg ha^{-1} and 78.88 kg ha^{-1}, respectively) with 100% RDF through fertigation and plastic polythene mulch. Unlike conventional fertilizer application, fertigation ensures uniform distribution of nutrient solution at the root zone and this increases the nutrient uptake and facilitates better translocation of photosynthates from source to sink (Saileela*et al.*,2017) [28]. A properly designed fertigation system delivers nutrients and water in such a way that it maximises the nutrient uptake (Gardenas*et al*., 2005) [9]. Mulching with polythene supress the weed growth and facilitates good quantity moisture retension. Thus these reasons could be attributed for higher uptake of nutrients due to the conjunctive influence of mulching with polyethyene plastic and of fertigation of 100 per cent RDF.

Different levels of fertigation and different mulching conditions had a significant influence on the nutrient use efficiency. The nutrient use efficiency was maximum(157.09 kg pod per kg nitrogen, 94.61 kg pod per kg phosphorus and 125.57 kg pod per kg potassium) in fertigation with 100% RDF when compared to other levels of fertigation and application of 100% RDF through soil application. The use of plastic polythene mulch resulted in higher nitrogen use efficiency (161.50 kg pod per kg nitrogen) phosphorus use efficiency (97.22 kg pod per kg phosphorus) and potassium use efficiency (130.25 kg pod per kg potassium) when compared to paddy straw mulch and no mulch. In the interactions it was found that the nutrient use efficiency was higher (178.35 kg pod per kg nitrogen, 106.30 kg pod per kg phosphorus and 126.56 kg pod per kg potassium) with 100% RDF through fertigation and plastic polythene mulch. Fertigation, the judicious application of fertilisers along with irrigation, proved to be the principal factor that enhance yield (Ningaraju and Joseph, 2014 Sathish*et al*., 2014) [23, 29]. The production and accumulation of dry matter and nutrients in a plant is inluenced by the management practices adopted (Meenakshi *et al*., 2008) [22]. Fertigation and plastic mulching proved to improve growth by providing optimum nutrient availability conditions for nutrient absorption. These might be the reasons for better nutrient use efficiency with the combined application of plastic mulch and fertigation with 100% RDF.

The water use efficiency exhibited significant difference among different levels of fertigation and different mulching conditions (Table 3). The water use efficiency was maximum (441.23 kg ha^{-1} cm^{-1}) in fertigation with 100% RDF when compared to other levels of fertigation and application of 100% RDF through soil application. Water use efficiency was higher (454.59 kg ha^{-1} cm^{-1}) when plastic polythene mulch was used when compared to paddy straw mulch and no mulch. The water use efficiency was higher (504.02 kg ha^{-1} cm^{-1}) in the interactions of 100% RDF through fertigation and plastic polythene mulch as well. Fertigation helps in better root growth and shoot growth in a plants due to luxurient supply of nutrients. Plastic mulching reduces the moisture loss from the soil surface and increases the availability of moisture for plant growth. These could be the reasons attrributed for higher water use efficiency with mulching and application of 100% RDF through fertigation. Similar results were obtained by Bagali*et al.*, (2012) [6] and Anjitha (2020) [1] in onion.

Among the different levels of fertigation and different mulches, physiological loss in weight shelf life of the pods, moisture content in pods, firmness of the pods and crude fibre content in pods exhibited significant difference as depicted in table 4. The treatment consisting of 100% RDF through fertigation has shown lower physiological loss in weight (51.53%), higher shelf life of the pods (6.82 days), higher moisture content in pods (87.79%), higher firmness of the pods (3.93 kg cm^{-2}) and higher crude fibre content (15.85%) when compared to other levels of fertigation and application of 100% RDF through soil application. Plastic polythene mulch resulted in lower physiological loss in weight(53.54%), higher shelf life of the pods (6.90 days), higher moisture content in pods (86.87%), higher firmness of the pods (3.64 kg cm^{-2}) and higher crude fibre content (15.63%).Among the interactions between mulches and fertigation levels lower physiological loss in weight(48.25%), higher shelf life of the pods (8.05 days), higher moisture content in pods (89.05%), higher firmness of the pods (4.05 kg cm^{-2}) and higher crude fibre content (16.19%) were documented in 100% RDF through fertigation and plastic polythene mulch. Nitrogen, phosphorus and potassium are the most indispensable nutrients for growth and development of plants, as they are the fundamental constituents of all living matter. Luxurient availability of nutrients will facilitate the synthesis and accumilation of carbohydrates and proteins in the reproductive parts of the plant. Hence the pods have exhibited higher moisture content, fibre content, firmness, good shelf life and less physiological loss in weight. Similar results were obtained by Vidhyashree (2017) [32] and Udaykumar (2019) [31].

Table 1: Effect of different levels of fertigation and mulches on growth parameters of french bean.

Treatment	Plant height (cm)	Number of primary branches	Leaf area (cm^2)	Leaf area index
Main plot				
F1: 50% RDF through fertigation	47.78	5.35	450.48	0.71
F2: 75% RDF through fertigation	48.35	5.91	488.85	0.79
F3: 100% RDF through fertigation	50.88	6.33	533.61	0.97
F4: 100% RDF through soil application	46.18	5.24	376.85	0.63
S.Em±	1.28	0.03	3.04	0.01
C.D.@5%	N/A	0.10	8.78	0.01
Sub plot				
M1: Paddy straw	48.81	5.70	464.11	0.77
M2: Plastic polythene	48.29	5.84	480.74	0.83
M3: No mulch	47.78	5.58	442.49	0.73
S.Em±	1.22	0.08	5.77	0.01
C.D.@5%	N/A	0.24	17.80	0.02
Interaction				
M1F1	48.45	**5.37**	454.90	0.72

M1F2	47.88	5.36	457.74	0.77
M1F3	47.01	5.33	438.79	0.63
M2F1	48.94	5.87	493.71	0.79
M2F2	50.14	6.06	509.16	0.83
M2F3	45.96	5.79	463.69	0.76
M3F1	50.46	6.32	538.95	0.95
M3F2	51.55	6.64	564.54	1.06
M3F3	50.63	5.99	497.33	0.91
M4F1	47.40	5.22	368.87	0.61
M4F2	43.61	5.29	391.52	0.67
M4F3	47.54	5.20	370.15	0.62
S.Em±	2.41	0.07	6.09	0.01
C.D.@5%	N/A	0.20	17.56	0.02

Table 2: Effect of different levels of fertigation and mulching on yield parameters in french bean.

Treatment	Number of pods per cluster	Number of pod clusters per plant	Yield per plant (g)	Yield per hactere (t ha^{-1})
Main plot				
F1: 50% RDF through fertigation	8.59	5.59	77.24	8.95
F2: 75% RDF through fertigation	9.15	6.31	77.06	9.15
F3: 100% RDF through fertigation	9.76	7.14	77.68	9.57
F4: 100% RDF through soil application	8.23	5.91	77.27	9.26
S.Em±	0.05	0.06	1.19	0.07
C.D@5%	0.16	0.17	3.55	0.22
Sub plot				
M1: Paddy straw	8.89	6.11	76.28	8.68
M2: Plastic polythene	9.15	6.40	79.24	10.52
M3: No mulch	8.76	6.21	76.41	8.38
S.Em±	0.02	0.05	1.69	0.09
C.D@5%	0.07	0.15	5.12	0.28
Interaction				
M1F1	8.24	5.51	76.07	8.69
M1F2	8.84	5.87	77.89	9.58
M1F3	8.70	5.40	77.76	8.58
M2F1	9.17	6.00	77.24	8.80
M2F2	9.27	6.25	77.47	10.25
M2F3	9.02	6.60	76.86	8.42
M3F1	9.78	6.95	77.76	8.18
M3F2	10.02	7.41	80.94	11.58
M3F3	9.50	7.08	74.34	8.68
M4F1	8.38	5.98	74.44	8.28
M4F2	8.47	6.07	80.68	9.05
M4F3	7.84	5.68	76.70	8.07
S.Em±	0.11	0.12	2.41	0.14
CD@5%	0.33	0.35	7.27	0.43

Table 3: Effect of different levels of fertigation and mulching on uptake of nutrients in french bean

Treatment	Nitrogen uptake (kg ha^{-1})	Phosphorous Uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})
Main plot			
F1: 50% RDF through fertigation	68.28	8.20	69.64
F2: 75% RDF through fertigation	74.81	8.33	73.02
F3: 100% RDF through fertigation	88.03	8.91	78.88
F4: 100% RDF through soil application	64.35	8.46	75.65
S.Em±	0.43	0.19	0.49
C.D@5%	0.32	0.46	1.44
Sub plot			
M1: Paddy straw	74.41	8.42	75.10
M2: Plastic polythene	78.01	8.87	77.94
M3: No mulch	69.17	7.81	69.34
S.Em±	0.2	0.17	0.56
C.D@5%	1.32	0.53	1.66
Interaction			
M1F1	66.08	7.89	74.04
M1F2	74.24	9.49	70.99
M1F3	64.51	7.96	63.89
M2F1	78.84	8.52	67.08
M2F2	79.15	7.60	74.46

M2F3	66.44	9.10	77.52
M3F1	88.48	8.15	78.26
M3F2	92.30	8.21	80.91
M3F3	83.27	9.25	77.48
M4F1	64.25	8.00	77.95
M4F2	66.30	8.12	75.11
M4F3	62.48	7.02	71.96
S.Em±	0.42	0.28	0.94
CD@5%	1.21	0.65	2.88

Table 4: Effect of different levels of fertigation and mulching of nutrient use efficiency and water use efficiency in french bean.

Treatment	Nitrogen use efficiency. (kg of pods kg^{-1} N)	Phosphorous use efficiency (kg of pods kg^{-1}P)	Potassium use efficiency (kg of pods kg^{-1} K)	Water use efficiency (Kg $ha^{-1}cm^{-1}$)
Main plot				
F1: 50% RDF through fertigation	154.30	92.92	117.53	433.57
F2: 75% RDF through fertigation	146.85	88.81	122.82	411.66
F3: 100% RDF through fertigation	157.09	94.61	125.57	441.23
F4: 100% RDF through soil application	149.63	90.27	122.29	4.13
S.Em±	1.16	0.92	0.39	12.55
C.D@5%	3.57	2.83	3.10	
Sub plot				
M1: Paddy straw	148.12	89.32	118.79	415.45
M2: Plastic polythene	161.50	97.22	130.25	454.59
M3: No mulch	146.28	88.19	117.12	419.87
S.Em±	1.46	1.14	1.23	3.44
C.D@5%	4.30	3.45	3.73	10.31
Interaction				
M1F1	148.30	89.43	118.94	415.94
M1F2	157.24	95.06	118.36	442.15
M1F3	157.38	94.26	115.30	442.61
M2F1	150.04	90.53	120.40	421.08
M2F2	146.57	88.30	131.97	410.60
M2F3	143.96	86.20	116.10	403.23
M3F1	154.01	93.03	123.73	432.72
M3F2	178.35	106.30	126.56	504.02
M3F3	138.91	84.50	126.43	386.96
M4F1	140.15	84.30	112.11	392.07
M4F2	163.85	99.23	144.12	461.53
M4F3	144.91	87.30	110.12	406.02
S.Em±	2.37	1.86	2.05	6.85
CD@5%	7.06	5.66	6.20	20.62

Table 5: Effect of different levels of fertigation and mulching on the quality parameters of french beans

Treatment	Physiological loss in weight (%)	Shelf life (days)	Moisture content (%)	Firmness (kg/cm^2)	Crude fibre content (%)
Main plot					
F1: 50% RDF through fertigation	56.78	6.44	84.46	3.35	15.24
F2: 75% RDF through fertigation	53.78	6.67	86.08	3.47	15.21
F3: 100% RDF through fertigation	51.53	6.82	87.97	3.93	15.85
F4: 100% RDF through soil application	58.67	6.00	82.01	3.36	15.25
S.Em±	1.20	0.14	0.79	0.06	0.03
C.D.@5%	4.24	0.48	2.72	0.22	0.09
Sub plot3.37					
M1: Paddy straw	55.08	6.33	84.63	3.37	15.13
M2: Plastic polythene	53.54	6.90	86.87	3.64	15.63
M3: No mulch	57.00	6.17	83.90	3.32	15.40
S.Em±	0.91	0.09	0.42	0.02	0.02
C.D.@5%	2.74	0.27	1.26	0.07	0.06
Interaction					
M1F1	55.00	**6.33**	84.23	3.26	13.73
M1F2	58.67	6.67	86.00	3.48	15.64
M1F3	56.67	6.33	83.13	3.32	16.35
M2F1	51.33	6.67	84.90	3.38	14.24
M2F2	53.00	7.00	86.83	3.71	14.93
M2F3	57.00	6.33	86.50	3.30	16.46
M3F1	55.33	6.33	86.57	3.53	16.46

M3F2	48.25	8.00	89.63	4.05	16.19
M3F3	52.00	6.00	87.23	3.37	14.83
M4F1	58.67	6.00	82.80	3.28	16.07
M4F2	55.00	6.00	84.50	3.50	15.73
M4F3	62.33	6.00	78.72	3.28	13.64
S.Em±	1.81	0.18	0.84	0.05	0.04
C.D.@5%	5.43	0.54	2.52	0.14	0.13

Conclusion

From the investigation it can be concluded that the application of 100% RDF through fertigation exhibited higher pod yield and good quality pods. Thus fertigation helps to obtain good quantity and quality of french beans. Use of plastic mulch resulted in higher growth and yield of pods in french beans. The combination of plastic mulches and 100% RDF through fertigation also showed improved pod yield and quality of french beans. Hence, from the present research it can be concluded that 100 per cent RDF through fertigation and use of plastic polythene mulch is best suited for cultivation of french beans as it provides higher yields and good quality pods.

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