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Effect of Irrigation Frequency and Mulching Materials on Soil Properties, Growth and Yield of French Beans under Drylands: Rwamagana-Nyirabidibili case

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Abstract- The study examined the effect of irrigation frequency and mulching materials on French beans' soil properties, growth, and yield using a randomized block design with three blocks consisted of sixteen plots per block. Different Mulching materials and irrigation intervals were used and once watered as planned, 30mm of water (≈38.4 liters per plot) was added. After harvesting, soil samples were collected at 20cm depth and analyzed. On soil properties, the soil texture was sandy clay loam, and irrigation frequency, mulching material, and interaction did not significantly affect texture, aggregate stability, soil pH, CEC and Organic matter. The soil pH ranged between 5.1-5.5which is slightly acidic the soil CEC ranged between 40.2 to 51.7Cmol/kg, and organic matter ranged between 3.43 and 4.47% which is moderately mummified. The impact of irrigation frequency and mulching material on plant height, number of leaves, leaf length, number of pods, length of pod and pod width while the interaction become not significant with an increase from 6.32-31cm in 15 days after sawing, 7.77-33.11 cm after 21days of sawing and 9.21-41.56 cm after 40 days of sawing in plant height, with an increase from 4.67-10 leaves within 32 days after sawing and 6.56-12.56 leaves after 50 days of sawing in number of leaves with an increase from 4.11-10.89 cm at 21 day of sawing and 6.56-12.56 cm after 36 days of sawing in leaf length and an increase in pods number from 7.33-36.22 pods after 67 days of sawing, 5.50-14.67cm in pods length after 68 days of sawing and 1.33-2.71cm in pods width (diameter) after 65 days of sawing. Mulching material significantly affected the yield of French beans, with irrigation frequency having a significant impact and the interaction effect of irrigation frequency and mulching material significantly affect yield of French beans with an increase from 1.52-10.61 T/Ha. Therefore the Rwandan savanna region is largely plagued by drought, which can be mitigated through mulching and improved water usage efficiency.

Keywords- Irrigation frequency, Mulching material, French beans, pod width, plant height, leaf length pod length, leaf length, CEC, pH, OM, Aggregate stability

I. INTRODUCTION

Since the turn of the century, the agricultural sector has grown at a rate of more than 5% per year, It is the most important sector of the Rwandan economy as in 2023 the services sector contributed 44% of GDP, the agriculture sector 27% of GDP as the second contributor to the Rwandan economy (NISR 2023). Phaseolus vulgaris, also known as beans, is a member of the fabaceae family of legumes and may be grown in a variety of climates (Chaurasia 2020). It remains one of the most significant meals consumed by humans today. The pods provide proteins, fiber, calcium, iron, folic acid, riboflavin (vitamin B2), vitamin C, and other nutrients to the human diet (Fabbri 2016), (NAEB 2018) and (Mahmood 2018). French green beans are both a legume and a vegetable, and they help with eye, heart, and diabetes management (NAEB 2018) According to the national horticulture policy of 2013, french beans were grown in Rwanda in substantial quantities, along with sweet peppers, leeks, and smaller amounts of peppers. 22647045kg of french beans were exported, earning the nation 5087584 dollars (NAEB 2014). Mulching is a crucial component of integrated pest management (IPM) (Iqbal, et al. 2020). Mulches may reduce water runoff, increase soil infiltration capacity, reduce weed growth by providing shade, and act as an evapotranspiration hurdle (Rathore 1998). According to (Kar and Kumar 2007), the mulch's improved availability of phosphate, potassium, and organic carbon may have aided in boosting crop development and yields, particularly in the mulched treatments. Other beneficial environmental impacts of mulching include regulating soil and plant root temperature, minimizing nutrient losses, reducing soil erosion and compaction, and improving the physical qualities of soil (Ngouajio and McGiffen 2004); (Lamont 2005). Improved yield parameter performance during mulching treatment were the result of increased water conservation, ideal soil moisture availability, and the subsequent impact on nutrient uptake and temperature moderation, which leads to better plant growth as resuts of mulching materials (Kwambe, et al. 2015) , (Abdelrahman, et al. 2016), (Gao, et al. 2020) and (Roosda, Ramdhani and Birnadi 2021)

It is now essential to increase water USE efficiency because water is required for the majority of plant operations and is currently the biggest problem facing many nations (Marwa, Hamza and Jun 2022). Increasing the amount of water applied to the plants increased plant height (Baker, Modi and Nciizah 2021)As a result, irrigation systems are among the most crucial factors determining the quantity and quality of agricultural products, and water needs to be applied at the right time and in the right amount. For better french beans growth, yield returns and soil physic-chemical properties conservation, it is vital to combine irrigation frequency with various mulching materials. As resut of combining irrigation frequency and mulching materials this is not only increase French beans productivity but also provide farmers with favorable financial returns and soil properties is conserved and protected from degradation (Iqbal, et al. 2020). Different researches had been conducted in mulching materials and irrigation frequency on French beans, but in Rwanda no more researches conducted on combination of irrigation frequency and different mulching materials on soil properties, growth and yield of French beans, in addition mulching materials are readily available and sometimes even free, people rarely use them on french beans, and efficient irrigation frequency and water application are still uncommon among small farmers. This study aims to fill these production gaps for french beans by assessing the effects of mulching materials and irrigation frequency on soil properties, growth and yield of french beans in savannah region especially, in Rwamagana of Eastern provence of rwanda.

II. RESEARCH METHODOLOGY

1. Soil Characterization of the Study Area

Disturbed soil samples were collected by using auger at a depth of 20 cm by using zigzag sampling technic and transferred to RP-Musanze soil laboratory for analysis of physico-chemical properties analysis after harvesting. Soil samples that were collected from Rwamagana 34 irrigation zone were air dried in boxes for two weeks, ground and sieved using 2mm mesh for soil properties analysis. The soil texture was assessed by using

hydrometric method (Bouyoucos 1962) (Day 1965), the aggregate stability was assessed by using comparative study of granulometric and texture results, In order to measure the soil pH, pH meter method was used, volumetric method was used for CEC determination, the loss on ignition procedure described by (Nelson and Sommers 1996) for organic matter determination.

2. Experimental Design and Field Inputs

The randomized complete block design with factorial arrangement of treatments in the field was designed, with four different mulching material including control, Maize straw, banana leaves and savannah grasses and four different irrigation frequency including; four day irrigation interval, seven days irrigation interval, ten days of irrigation interval and, thirteen days of irrigation interval with three blocks and each block consist of 16 treatments (Table 1).

Table 1: The table showing possible treatment in each repetition (block)

Factor 1: irrigation frequency	Factor 2: Mulching material	Treatments
I4	M0	I4M0
	MG	I4MG
	MM	I4MM
	MB	I4MB
I7	M0	I7M0
	MG	I7MG
	MM	I7MM
	MB	I7MB
I10	M0	I10M0
	MG	I10MG
	MM	I10MM
	MB	I10MB
I13	M0	I13M0
	MG	I13MG
	MM	I13MM
	MB	I13MB

3. Field Inputs

In order to grow french bean in designed plots, the organic manure were applied at a rate of 10ton/ ha, 100kg/ha of DAP were applied, the seeds of dwarf variety of Phaseolus vurgalis l. was planted by row to row at interval of 40 cm and plant to plant at interval of 20cm with 2cm deep in the soil, 30mm of water was applied in every irrigation day by surface flooding irrigation, Regular weed, pest and diseases checking and controlling were conducted to optimize plant growth and yield.

4. Data Collection and Analysis

Recording Data

In order to analyze the soil properties three (3) repetition were readied and averaged to obtain the real data. Plant data three different plants were selected randomly and measured in each plot and averaged. For plant height tape was used to record the data once in 15, 21 and 40 days after sawing, number of plant leaves were countered once in 32 and 50 days after sawing, leaves length measured using tape in 21 and 36 days after sawing, pods length and pods width was measured by using tape and number of pods were countered at 68, 65 and 67 days after sawing, pods weighing was recorded after each harvesting and balance with precision were used to record data yield weight after every harvesting. My research was conducted from May to December, 2023

5. Data Analysis

Data on agronomic and soil-related parameters were analyzed using GenStat Software Edition 14th. The treatment effects were analyzed for significance using the F-test at 5%. Means were separated using Ficher's protected least significant difference (LSD < 0.05).

III. RESULT AND DISCUSSION

1. Effect of Irrigation Frequency and Mulching Material on Soil Texture and Aggregate Stability

According to the results obtained, there is no significant effect of irrigation frequency on soil texture as $P > 0.05$, the mulching material also had not significantly affected the soil texture as $P > 0.05$ and the interaction of irrigation frequency and mulching material did not significantly affect soil texture where $P > 0.05$ (Table 2). The effect of mulching material on Aggregate stability is not significant as $P > 0.05$, Also the effect of irrigation frequency on aggregate stability is not significant as $P > 0.05$ and the interaction effect of mulching

material and irrigation frequency on Aggregate stability as P > 0.05 (Table 3). According to USDA soil texture triangle, it was still identified as sandy clay loam soil. These results are congruent with those of (Arjun 2015), who discovered that neither mineral additions nor the exponential application of FYM can change the textural class of soil similar results were also reported by (Ni, et al. 2016).

IF	Sand after %					Clay after %					Silt after %				
	M0	MB	MG	MM	Means	M0	MB	MG	MM	Means	M0	MB	MG	MM	Means
I4	61.22	61.22	61.55	60.67	61.17	20.44	20.22	21.11	20.67	20.61	18.33	18.55	17.34	18.66	18.22
I7	60.89	59.78	58.22	60.45	59.83	20.44	21.33	21.22	21.56	21.14	18.67	18.89	20.55	18.00	19.03
I10	58.89	60.67	60.67	61.45	60.42	20.33	21.56	21.56	21.00	21.11	20.78	17.77	17.77	17.55	18.47
I13	61.34	59.67	57.33	60.67	59.75	21.67	20.33	20.33	21.89	21.05	16.99	20.00	22.34	17.44	19.19
Means	60.59	60.34	59.44	60.8	60.29 GM	20.72	20.86	21.05	21.28	20.98GM	18.69	18.80	19.50	17.91	18.73 GM
LSD	MCM		IF		MCM*IF	MCM		IF		MCM*IF	MCM		IF		MCM*IF
CV%	2.8					3.9					10.5				

Table 2: Effect of irrigation frequency and mulching material on soil texture

Means without any letter along the row for the mulching material (MCM) and along the column for irrigation frequency (IF) are not significantly different at LSD ≤ 0.05 at protected Ficher's LSD

M0: no mulching material
MB: Mulching with Banana leaves
MG: Mulched with savanna Graces
MM: Mulched with maize straw
I4: 4 days irrigation frequency
I7: 7 days irrigation frequency
I10: 10 days irrigation frequency
I13: 13 days irrigation frequency

Table 3: Effect of irrigation frequency and mulching material on aggregate stability

MCMIF	Aggregate stability analysis				
	M0	MB	MG	MM	Means
I4	1.10	1.10	1.00	1.04	1.06
I7	1.09	1.06	1.06	1.15	1.09
I10	1.90	1.08	1.04	1.30	1.33
I13	1.11	1.12	1.07	1.09	1.10
Means	1.30	1.09	1.04	1.15	1.14(GM)
LSD	MCM 0.281		IF 0.281		MCM*IF 0.562
CV%	29.6				

Aggregate stability was calculated based on result obtained from granulometric measurement made

2. Effect of Irrigation Frequency and Mulching Materials on Soil Ph, CEC And Organic Matter

According to the result the soil pH range in slightly acidic soil, ranging between 5.1-5.5 (Table 4) and based on result analysis made, it is clear that there is no significant effect of irrigation frequency on soil pH as as P > 0.05 , the effect of mulching material on soil pH also is not significant as P > 0.05 , Also the interaction effect of irrigation frequency and mulching material on soil pH is not statistically significant as P > 0.05. Analysis made on soil CEC showed that there is no significant effect of mulching material on CEC obtained P > 0.05, the effect of irrigation frequency on CEC is not significant as P > 0.05

Table 4: Effect of irrigation frequency and mulching material on soil pH, OM and CEC

MCM IF	pH					OM %					CEC (Cmol/kg)				
	I4	I7	I10	I13	Means	I4	I7	I10	I13	Means	I4	I7	I10	I13	Means
M0	5.30	5.40	5.37	5.33	5.33	3.93	3.77	3.90	3.73	3.83	43.80	40.20	50.20	43.93	44.53
MB	5.30	5.40	5.43	5.30	5.33	4.07	4.37	4.33	4.23	4.25	45.40	42.90	42.73	51.60	45.66
MG	5.20	5.20	5.20	5.20	5.20	4.03	4.20	4.20	4.20	4.16	51.73	43.47	43.20	47.47	46.47
MM	5.30	5.33	5.17	5.27	5.27	4.27	4.30	3.43	4.20	4.05	51.53	47.27	47.27	41.53	46.90
Means	5.28	5.33	5.27	5.25	5.28 (GM)	4.08	4.16	3.97	4.09	4.07 (GM)	48.12	43.46	45.85	46.13	45.89(GM)
LSD	MCM 0.125		IF 0.125		MCM*IF	MCM 0.271		IF 0.271		MCM*IF	MCM 4.206		IF 4.206		MCM*IF
CV%	6.4					8.0					11.0				

Means without any letter along the row for the mulching material (MCM) and along the column for irrigation frequency (IF) are not significantly different at LSD ≤ 0.05

M0: no mulching material
MB: Mulching with Banana leaves
MG: Mulched with savanna Graces
MM: Mulched with maize straw
I4: 4 days irrigation frequency
I7: 7 days irrigation frequency
I10: 10 days irrigation frequency
I13: 13 days irrigation frequency

also by analyzing the interaction effect of irrigation frequency and mulching material on soil CEC showed that there is no interaction effect on CEC as $P > 0.05$ and the soil CEC ranges between 40.2 and 51.7Cmol/kg (Table 4) The organic matter range in moderately level (Table 4) and based on result analysis made the result showed that there is no significant impact of irrigation frequency on soil OM $P > 0.05$, also mulching material have no significant impact on soil OM $P > 0.05$, by analyzing the interaction effect of irrigation frequency and mulching material on soil OM it is clear that there is no significant effect the had on soil OM as $P > 0.05$. In harmony with prior studies by (Lal 2004) and (Bhattacharyya, et al. 2007), the mulching material influence on SOC can be linked to plant residues generated and returned to the soil, resulting in stable organic matter synthesis so, one agriculture season cannot easily generate the highly OM to change the status of soil content on OM. These findings are consistent with those of (Aiguo, et al. 2019), who discovered similar result on OM, according to (Katyal, Rao and Reddy 2001), a decline in soil organic content is almost invariably caused by agricultural intensification, which involves clearing and cleaning soils for yearly crops. In alignment with documentation of (Naramabuye, Haynes and Modi 2008) and (Castillo, Benito and Fernandez 2003)for the pymarc pH of 7.1, this pattern of proportionate increase in pH and organic carbon could be modified by applying calcium and magnesium rich materials to the soil but cannot easily changed by irrigation frequency or mulching material applied in the same season. The same conclusions were reached by (Kumar, et al. 2014)and (Hadiayompamungkas, et al. 2019), who showed that plant spacing inside and between rows had no effect on soil pH. Also (Ni, et al. 2016) find that there is no significant impact of irrigation frequency on soil pH, CEC and OM.

3. Effect of Irrigation Frequency and Mulching Material on Plant Height

The results of the plant parameters indicate that after 15 the longest plant found in I4MM with 31.00cm while the shortest plant height found in I13M0 with 6.32cm long which means there is an

increase by 20.39% in 15 day from smallest height to the longest plant height, by performing statistical analysis to test the null hypothesis it is found that the mulching material affect highly significant the plant height P < 0.001 (Annex 8), Also irrigation frequency have statistically highly significant affect the plant height at 15 days at P < 0.001(Table 5) but the interaction effect of irrigation frequency and mulching material did not significantly affect the plant height at 15 days after sawing as P > 0.05. After 21 days the highest plant height was found in I4MM with plant height of 33.11cm long while the shortest was found in I13M0 with 7.77cm long which means there is an increase of 23.46% after 21 days between shortest and longest plant height in average, by testing the null Hypothesis it found that there is a highly significant impact of irrigation frequency on plant height after 21 days at P < 0.001, also Mulching material have high significantly affected the plant height at 21 days after sawing with P < 0.001, it was found that there is no interaction effect of irrigation frequency and mulching material on plant height as P > 0.05 after 21 days of sawing. The result revealed that after 40 days of sawing the highest plant height obtained in I4MM with 41.56cm long and the shortest plant height was obtained in I13M0 with 9.21cm with an increase of 22.16% by testing the nul hypothesis it is found that the irrigation frequency have highly significant affect the plant height at P < 0.001, also the mulching materials have significant highly affect the plant height after 40 days of sawing at P < 0.001, by analyzing the interaction effect of irrigation frequency and mulching materials on plant height after 40 days, it was found that there is no interaction effect of irrigation frequency and mulching material on plant height as P > 0.05. These findings agree with those of (Meena, et al. 2019) and (Iqbal, Raza and Waqas, et al. 2021)Mulching may have resulted in improved plant growth in height due to the absence of competition, particularly for water and nutrients (Nwosisi, Nandwani and Hui 2019) (Datta, Saxena and Ghosh 2017), (Iqbal, et al. 2020) (Baker, Modi and Nciizah 2021). The result are in alignment with (Ni, et al. 2016) who found that mulching had a substantial impact on plant height. Furthermore, when moisture is scarce, processes such as cell division and enlargement, as well as photosynthesis, suffer, resulting in lower plant height. Moisture stress also induces stomatal closure and decreased CO2 and nutrient uptake by plants, which has a negative impact on plant growth. Low moisture has already been shown to reduce plant height (Kapoor, et al. 2020) (Singh, et al. 2021).

Table 5: Effect of irrigation frequency and mulching material on plant height

CV%	LSD		Means	I13	I10	I7	I4	MCM*IF	Plant height after 15 days (Cm)	Plant height after 21 days (Cm)	Plant height after 40 days (Cm)
21.2	MCM 3.16		7.50d	6.22	7.25	7.94	9.50	M0			
			16.76c	9.66	16.92	19.45	21.00	MB			
	IF 3.16		21.12b	12.40	22.09	22.95	25.95	MG			
			26.46a	19.38	26.19	29.28	31.00	MM			
	MCM*IF		17.96(GM)	11.96c	18.11b	20.15ab	21.61a	Means			
17.0	MCM 2.809		9.20d	7.77	9.02	9.71	10.28	M0			
			18.50c	12.16	17.86	20.22	23.78	MB			
	IF 2.809		23.26b	14.21	24.69	26.06	28.06	MG			
			28.57a	21.49	28.30	31.39	33.11	MM			
	MCM*IF		19.88(GM)	13.91c	19.97b	21.85ab	23.81a	Means			
15.6	MCM 3.274		11.72d	9.21	11.69	12.71	13.28	M0			
			21.21c	14.92	21.26	22.89	25.79	MB			
	IF 3.274		31.00b	21.71	32.64	33.84	35.82	MG			
			37.02a	29.93	36.74	39.83	41.56	MM			
	MCM*IF		25.24(GM)	18.92c	25.61b	27.32ab	29.11a	Means			

Means without any letter along the row for the mulching material (MCM) and along the column for irrigation frequency (IF) are not significantly different at LSD ≤ 0.05

M0: no mulching material
MB: Mulching with Banana leaves
MG: Mulched with savanna Graces
MM: Mulched with maize straw
I4: 4 days irrigation frequency
I7: 7 days irrigation frequency
I10: 10 days irrigation frequency
I13: 13 days irrigation frequency

4. Effect of Irrigation Frequency and Mulching Material on Number of Leaves

After 32 the result revealed that the highest number of leaves is in I4MB with 10.00leaves in average and the least one was found in I13M0 with 4.67 Leaves in average it means there is 46.7% in difference, by testing a null hypothesis it was found that the irrigation frequency have statistically highly affected the number of leaves as P < 0.001 also mulching materials have statistically highly affect the number of leaves at P < 0.001, but the interaction effect of irrigation frequency and mulching materials have no effect on number of leaves at 32 days as P > 0.05. And in 50 days after sawing the highest number of leaves had found in I4MB with 12.56 leaves in average and the least one was found in I13M0 with 6.56 leaves in average it means there is 52.23% in difference, by testing a null hypothesis it was found that the irrigation frequency have statistically highly affected the number of leaves as P < 0.001 and mulching materials have statistically highly affect the number of leaves at P < 0.001 but the interaction effect of irrigation frequency and mulching materials have no effect on number of leaves at 50 days as P > 0.05(Table 6). The findings are in agreements with the findings of (Chi, et al. 2021) who found the significant effects on the number of leaves due to irrigation frequency and mulching material. Furthermore, (Carmichael, et al. 2012)found a statistically significant association between leaf number and leaf area index. Mulching provides the root zone with ideal conditions for growth by retaining nutrients (due to reduced volatilization), moisture, and warmth. In agreement with results of (Tarara 2009) and (Kwambe, et al. 2015) both found that due to irrigation and mulching material this lead to roots developed faster, resulting in faster plant growth.

Table 6: Effect of irrigation frequency and mulching material on number of leaves

MCM / IF	Number of leaves after 32 days of sawing					Number of leaves after 50 days of sawing				
	M0	MB	MG	MM	Means	M0	MB	MG	MM	Means
I4	8.78	10.00	9.22	8.56	9.139 a	10.78	12.56	11.89	11.00	11.556 a
I7	6.00	7.67	8.44	6.89	7.250 b	8.44	10.89	10.89	10.67	10.222 b
I10	5.42	6.44	6.87	6.76	6.371 c	7.76	9.53	10.09	9.76	9.284 bc
I13	4.67	6.33	5.67	5.11	5.444 d	6.56	9.55	9.11	9.44	8.666 c
Means	6.217 b	7.609 a	7.550 a	6.828 ab	7.05(GM)	8.384 b	10.633a	10.495a	10.217 a	9.93(GM)
LSD	MCM 0.789		IF 0.789		MCM*IF 1.579	MCM 1.112		IF 1.112		MCM*IF 2.224
CV%	13.5					13.5				

Means without any letter along the row for the mulching material (MCM) and along the column for irrigation frequency (IF) are not significantly different at LSD ≤ 0.05

M0: no mulching material
MB: Mulching with Banana leaves
MG: Mulched with savanna Graces
MM: Mulched with maize straw
I4: 4 days irrigation frequency
I7: seven days irrigation frequency
I10: 10 days irrigation frequency
I13: 13 days irrigation frequency

5. Effect of Irrigation Frequency and Mulching Material on Leaves Length

The plants mulched with maize straw showed the longest leaves after 21 measuring I4MM measuring10.89cm long in average, while the shortest was found in I13M0 with 4.67cm by testing the hypothesis it is found that there is a highly significant impact of irrigation frequency on leaf length with $P < 0.001$, also mulching material have highly significant affected the leaf length as $P < 0.001$ by analyzing the interaction effect of irrigation frequency and mulching material it is found that there is no significant impact of irrigation frequency and mulching material on leaf length as $P > 0.05$. After 36 days longest leaves was found in I4MM measuring 13.94 cm long in average, while the shortest was found in I13M0 with 5.97cm by testing the hypothesis it is found that there is a highly significant impact of irrigation frequency on leaf length with $P < 0.001$, also mulching material have highly significant affected the leaf length as $P < 0.001$, by analyzing the interaction effect of irrigation frequency and mulching material it is found that there is no significant impact of irrigation frequency and mulching material on leaf length as $P > 0.05$ at 36 days after swing(Table 7) in agreement with result of (Chi, et al. 2021) discovered a noteworthy influence on the length of leave. Furthermore, a statistical correlation between leaf number and leaf area index was established by (Carmichael, et al. 2012). Because mulching retains moisture, warmth, and nutrients better than other methods (due to decreased volatization), the root zone is given ideal growing conditions. Warm roots caused faster root growth, which in turn caused faster plant growth, according to studies by (Kwambe, et al. 2015)and (Tarara 2009)

Table 1: Effect of irrigation frequency and mulching material on leaves length

MCM / IF	Leaf length after 21 days (Cm)					Leaf length after 36 days of sawing (Cm)				
	M0	MB	MG	MM	Means	M0	MB	MG	MM	Means
I4	6.11	9.33	9.22	10.89	8.889 a	8.78	12.78	11.94	13.94	11.861a
I7	4.89	7.56	8.67	9.56	7.667 a	8.33	10.39	10.83	11.39	10.236 b
I10	4.22	6.78	6.28	6.89	6.039 b	6.28	9.55	8.72	9.94	8.623 c
I13	4.11	6.31	5.59	6.20	5.552 b	5.97	8.62	7.23	8.84	7.666 c
Means	4.833 b	7.494 a	7.438 a	8.383 a	7.04 (GM)	7.338b	9.683 a	10.336 a	11.030 a	9.60 (GM)
LSD	MCM 1.316		IF 1.316		MCM*IF	MCM 1.408		IF 1.408		MCM*IF 2.816
CV%	22.5					17.6				

Means without any letter along the row for the mulching material (MCM) and along the column for irrigation frequency (IF) are not significantly different at LSD ≤ 0.05

M0: no mulching material
MB: Mulching with Banana leaves
MG: Mulched with savanna Graces
MM: Mulched with maize straw
I4: 4 days irrigation frequency
I7: 7 days irrigation frequency
I10: 10 days irrigation frequency
I13: 13 days irrigation frequency

6. Effect of Irrigation Frequency and Mulching Materials on Pods Number, Length of Pod and Pod Width

Regarding the number of french beans pods number the highest pods number is found in I4MM with 36.22 in average and the least one in pods number is I13M0 with average of 7.33 after 67 days, it implies a difference of 20.24%, by performing the hypothesis test it is clear that the mulching material had significantly affected the number of pods at $P < 0.001$, also the irrigation frequency have significantly affected the pods number at $P < 0.001$ but the interaction effect of irrigation frequency and mulching material is not statistically significant with $P > 0.05$ (Table 8). By assessing the width of pods the biggest pods were found in I4MG with 2.82cm in circumference while the smallest in size were found in I13M0 with 1.33cm 65 days of sawing in circumference which implies 47.2% in increasesin testing hypothesis it is found that the mulching material have highly significant affected the width of pods at $P < 0.001$, also the irrigation frequency have significantly affect the pods width at $P < 0.001$ but the interaction effect of irrigation frequency and mulching material did not significantly affect the pod width as $P > 0.059$(Table 8). For the results of pod length obtained it is found that the longest pods were obtained in I4MM with14.67cm long while the shortest was obtained in I113M0 with 5.5cm long in average after 68 days after sawing, by performing statistical test it is found that the mulching material have highly significant affect the length of pods at $P < 0.001$ also the irrigation frequency have highly significant affected the length of pods at $P < 0.001$, but the interaction of irrigation frequency and mulching material on pod length did not significantly affect the length of pods as $P > 0.05$(Table 8). The number of pods, length of pods and pods width per plant increased as the amount of water increased (Abd El-Wahed 2017) in harmony with result of (Ustin 1997)and (Sezen SM 2006)a comparable relationship was documanted. Mulch increased plant growth and yield (Mozunder S.N. 2005) They also found that increasing the amount of water applied to the plants increased plant height and yield and mulch decreased evaporation and enhanced the hydraulic characteristics of the soilalso mulch had prevented weeds from growing, which would have reduced competition for nutrients and water, which would have enhanced plant growth and height (Nwosisi, Nandwani and Hui 2019), (Datta 2017), (Iqbal, et al. 2020) and (Baker, Modi and Nciizah 2021).

Table 8: Effect of IF and MCM on pods number, length of pods and pods width

MCM IF	Pods number after 67 days					Length of pods after 68 days (Cm)					Pods width after 65 days(Cm)				
	M0	MB	MG	MM	Means	M0	MB	MG	MM	Means	M0	MB	MG	MM	Means
I4	19.11	33.89	34.33	36.22	30.89 a	9.78	13.78	14.56	14.67	13.19 a	2.22	2.71	2.82	2.71	2.617 a
I7	17.33	29.56	30.22	31.00	27.03 b	7.39	11.62	10.89	12.33	10.56 b	1.71	2.67	2.28	2.28	2.233 b
I10	14.33	22.60	23.78	22.44	20.79 c	7.83	10.95	10.33	11.33	10.11 b	1.47	1.94	2.17	1.67	1.811 c
I13	7.33	16.67	19.64	19.09	15.68 d	5.50	9.17	9.78	9.17	8.40 c	1.33	1.72	1.40	1.68	1.536 c
Means	14.53b	25.68 a	26.99 a	27.19 a	23.60(GM)	7.63 b	11.38 a	11.39 a	11.88 a	10.57(GM)	3.264a	2.167a	2.082a	1.683b	2.05(GM)
LSD	MCM 3.321		IF 3.321		MCM*IF	MCM 0.979		IF 0.979		MCM*IF	MCM 0.276		IF 0.276		MCM*IF
CV%	16.9					11.1					16.2				

Means without any letter along the row for the mulching material (MCM) and along the column for irrigation frequency (IF) are not significantly different at LSD ≤ 0.05

M0: no mulching material
MB: Mulching with Banana leaves
MG: Mulched with savanna Graces
MM: Mulched with maize straw
I4: 4 days irrigation frequency
I7: 7 days irrigation frequency
I10: 10 days irrigation frequency
I13: 13 days irrigation frequency

7. Effect of Irrigation Frequency and Mulching Material on Weight of Pods (Yield)

The maximum yield also was obtained in I4MG with yield of 10.72 t/ha and the lowest yield is I13M0 with general yield of 1.52 t/ha which implies an increase to 14.18%, by testing the null hypothesis it was found that the mulching material have highly significant affected the yield of french beans at P< 0.001, also irrigation frequency had high significantly affected the yield at P< 0.001 also the interaction effect of irrigation frequency and mulching material have significant effect on yield at P< 0.05 (Table 9)

These results agreed those of (Abd El-Wahed 2017), who observed that mulching and irrigation frequency had a substantial impact on all of the yield parameters they examined.

(Pushpavalli, et al. 2014) And (Nadeem, et al. 2019) concur with our findings. Increased water conservation, optimal soil moisture availability, and the resulting impact on nutrient uptake and temperature moderation, which leads to better plant growth, may be the cause of improved yield parameter performance under mulching treatment.

The current results are consistent with that of (Kwambe, et al. 2015), (Abdelrahman, et al. 2016), (Gao, et al. 2020), and (Roosda, Ramdhani and Birnadi 2021)

Table 9: Effect of irrigation frequency and mulching material on weight of pods (yield)

MCMIF	Yield after harvesting (T/Ha)				
	M0	MB	MG	MM	Means
I4	4.76	9.44	10.72	10.61	8.88 a
I7	3.57	6.30	8.81	9.37	7.01 b
I10	3.42	6.38	5.98	6.92	5.67 c
I13	1.52	4.56	4.38	3.47	3.49 d
Means	3.32 b	6.67 a	7.47 a	7.59 a	6.26(GM)
LSD	MCM 0.99		IF 0.99		MCM* IF 1.98
CV%	19.0				

Means without any letter along the row for the mulching material (MCM) and along the column for irrigation frequency (IF) are not significantly different at LSD ≤ 0.05

M0: no mulching material
MB: Mulching with Banana leaves
MG: Mulched with savanna Graces
MM: Mulched with maize straw
I4: 4 days irrigation frequency
I7: 7 days irrigation frequency
I10: 10 days irrigation frequency
I13: 13 days irrigation frequency

Correlation Analysis between Soil Organic Matter (OM), Ph, CEC and Yield

The correlations between Organic matter (OM) and pH, OM and CEC+, PH and yield, and OM and yield was also positively correlated and statistically significant ($p<0.01$) (Figure 1). in alignment with result of (Naramabuye, Haynes and Modi 2008), it was suggested that rising soil pH and CEC were the result of rising organic matter, which in turn led to rising organic carbon., according to the findings of (Aiguo, Jie, et al. 2019), they demonstrated a favourable association of those soil nutrients. Consequently, the plants become more nutrient available due to the rise in pH and CEC, which has a major impact on plant development and crop harvest, (Jenifer, Yost and Alfred 2019) confirmed similar findings. Furthermore, an increase in organic carbon led to the development of more soil aggregates, which in turn increased soil Water Holding Capacity which result in yield increase (El Sayed 2015). It's possible that the earlier split

nutrient treatment produced faster, more balanced root growth, which raised yield (Kotsyuk 1995.)

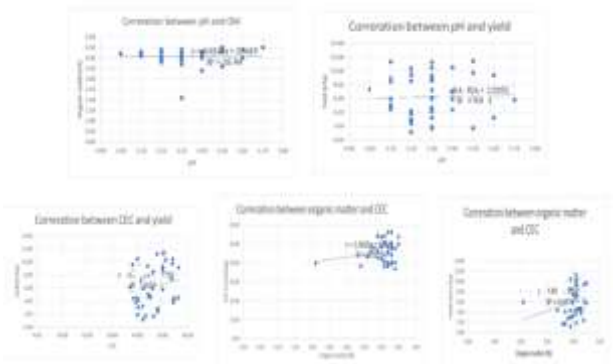

Figure 1: Correlation between soil organic matter, pH, CEC and yield

IV. CONCLUSION & RECOMMENDATIONS

This study evaluated the effect of irrigation frequency and mulching material on soil properties, growth and yield of french beans. Based on the USDA soil texture triangle, it was found that the soil texture was a sandy clay loam. The aggregate stability ranged from 1.04 to 1.90, and neither the irrigation frequency nor the mulching material's interaction had a significant impact on the soil texture, Based on the results of the analysis, it is evident that the pH range of slightly acidic soil is between 5.1 and 5.5. Additionally, there is no statistically significant effect of irrigation frequency on soil pH as determined by $P > 0.05$, nor is there a significant effect of mulching material on soil pH. Moreover, there is no statistically significant interaction between irrigation frequency and mulching material on soil pH. The CEC values of the soil vary from 40.2 to 51.7 Cmol/kg. The results of the analysis indicate that mulching material does not significantly affect CEC ($P > 0.05$), and irrigation frequency does not significantly affect CEC ($P > 0.05$). Additionally, it was determined that there is no interaction effect on CEC as $P > 0.05$ by analysing the impact of mulching material and irrigation frequency on soil CEC. According to the results of the analysis, the organic matter range is moderately level. The findings indicated that neither irrigation frequency nor mulching material had a significant impact on soil OM $P > 0.05$. It is evident from examining the interaction between irrigation frequencies and mulching material on soil OM that neither factor had a significant impact on soil OM $P > 0.05$. Testing a null hypothesis after 32 and 50 days of sawing, it was found that the frequency of irrigation had a statistically significant impact on the number of leaves ($P < 0.001$). Additionally, mulching materials have a statistically significant impact on the quantity of leaves ($P < 0.001$), although after 32 and 50 days, there is no interaction between irrigation frequency and mulching materials ($P > 0.05$). Following 21 and 36 days of cutting, it is discovered that irrigation frequency has a highly significant impact on leaf length ($P < 0.001$), and mulching material has a highly significant impact on leaf length ($P < 0.001$). The analysis of the interaction effect between mulching material afrequency of irrigation reveals that there is no significant influence of either on leaf length, with a $P > 0.05$ value. Additionally, it was discovered that the mulching material had a substantial impact on the quantity, length, and width of pods at $P < 0.001$. Additionally, the length and width of the pods, as well as the frequency of irrigation, have all been considerably impacted at $P < 0.001$, while the interaction between mulching material and irrigation frequency is not statistically significant at $P > 0.05$. The yield of french beans was shown to be significantly impacted by the mulching material at $P< 0.001$. Additionally, the yield was strongly impacted by irrigation frequency at $P< 0.001$. Additionally, at $P< 0.05$, the interaction between mulching material and irrigation frequency had a significant impact on yield. Consequently, applying mulch maintains soil moisture and controls temperature, which leads to better growth and an increase in yield, taking into account the effect of mulching on plant physiology and growth. Finally, since this Rwandan savanna region is primarily affected by drought issues, which can be impeded by mulching and water use efficiency, it is advised to apply mulching for the improvement of water use efficiency and yield increase.

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