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Response of Competition Indices to Row Configuration in Sorghum (Sorghum Bicolor L.)- Mung Bean (Vigna Radiata L.) Intercropping and seed proportion of mung bean in Additive Series in Semi-Arid Area of Wag Hemira Zone, Ethiopia

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***Abstract*— In the dry land areas, intercropping is the right options in improving yield due to erratic rainfall distribution. A proper crop combination, optimal plant population, and suitable row configuration are of paramount importance in intercropping systems. Sorghum-mung bean intercropping is common in the semi-arid Wag-Hemira Zone, Ethiopia, with sorghum as the main crop. However, optimal row configuration and seed proportion have not been studied. Therefore, a field experiment was conducted at Aybra to determine the ideal mung bean seed proportion and row arrangement for maximum productivity and profitability in an additive intercropping system. Three seed proportions of mung bean (200%, 100%, and 67%), and four row configurations (1S:1M, 2S:1M, 1S:2M, and 3S:1M) with two sole cropping systems as check in additive series in Randomization block design (RCBD) with three replications in factorial arrangement. The collected parameters were analysis using SAS software. The land equivalent ratio (LER), competitive ratio (CR), area-time equivalent ratio (ATER), monetary advantage index (MAI) were calculated. The highest total LER (1.39) and MAI (57119, 48971 ETB ha-1) were obtained when 67% of the seed was planted in the 1S:1M row ratio. The highest marginal rate of return (2094.203) was observed when a 200% seed rate of mung bean was planted in a 1S:1M row ratio. Therefore, based on the superior compatibility, and economic benefit, intercropping of sorghum with mung bean in a 1S:1M ratio with 67% seed proportion, followed by 200% seed proportion of mung bean is recommended for the study area and similar agro ecology.**

Keywords*— competitive ratio, intercropping, Land equivalent ratio, monitory advantage index, seed proportions

I. Introduction

Sorghum (Sorghum bicolor L.) the family Poaceae, specifically the subfamily andropogoneae [9]. About 80% of Ethiopia's total sorghum production comes from the two main producing regions, Oromiya and Amhara [8]. It used to make local beverages, feeds to animals, and build their homes from the stalks [4, 11 and 12].The mung bean (Vigna radiata (L) Wilczek), also known as the dry bean or golden gram, represents a significant source of nutrition and income for smallholder farmers in Africa [14].Cereal-legume intercropping is particularly important for sustainable food production systems, especially in situations where farmers use little or no fertilizer, fragmented land [7] and helps to conserve water and soil in certain landforms [5], provide consistent yield [17], and aid in weed control, improve quality, extend availability and conserve forage [2]. A frequently utilized metric for evaluating the land productivity of intercropping systems is the land equivalent ratio (LER) [16, 15, and 18]. One significant metric demonstrating the financial advantages of intercropping over mono cropping is the monetary benefit index (MAI) [21]. MAI provides a means of assessing the economic viability of intercropping in comparison to solitary cropping [20]. The competitive ratio (CR) and the area-time equivalent ratio (ATER) provide a more realistic assessment of the yield advantage of intercropping over mono cropping in terms of nutrient competitive and time [21].

In the semi-arid area of Wag-Hemira administrative zone, sorghum is a primary crop cultivated, followed by mung beans. However, the practice of continuous monoculture of sorghum has resulted in a decline in yields and a reduction in soil fertility. There is lack of knowledge regarding the specific seed proportions of mung bean and the optimal row arrangements of sorghum-mung bean row configuration for effective land use efficiency in the area. Furthermore, no research has been conducted in the study areas on the effects of seed proportions of mung bean and intercropping row ratio of mung bean with sorghum on land use efficiency and economic benefits. As a result, it is challenging to make recommendations regarding the seed proportions of mung bean and the intercropping row ratio of mung bean intercropping with sorghum in the study area. Accordingly, the objective of this experiment was to identify the most efficient land use through the analysis of various competition indices in sorghum-mung bean intercropping systems and to evaluate the profitability of sorghum-mung bean intercropping in comparison to the respective sole cropping systems in Wag-Heimra, Sekota district.

II. Material and Methods

A. Description of the Study Area

The experiment was carried out in Sekota district under Wag-Hemira administrative zone, in Sekoat Dry land Agricultural Research Site (Aybra main research site) during 2023 under rain-fed conditions. The district's agro ecology ranges from Woyna Dega (midlands) to Kola (lowlands). The research location is located at an altitude of 1915 meters above sea level and has geographic coordinates of 79^0 01, 08, E" N latitude and 12^0, 43, 38", N E longitude with maximum and lowest temperatures of 24.70 ^{0}C and 13.60 ^{0}C respectively with a total annual rainfall of 498.4 mm.

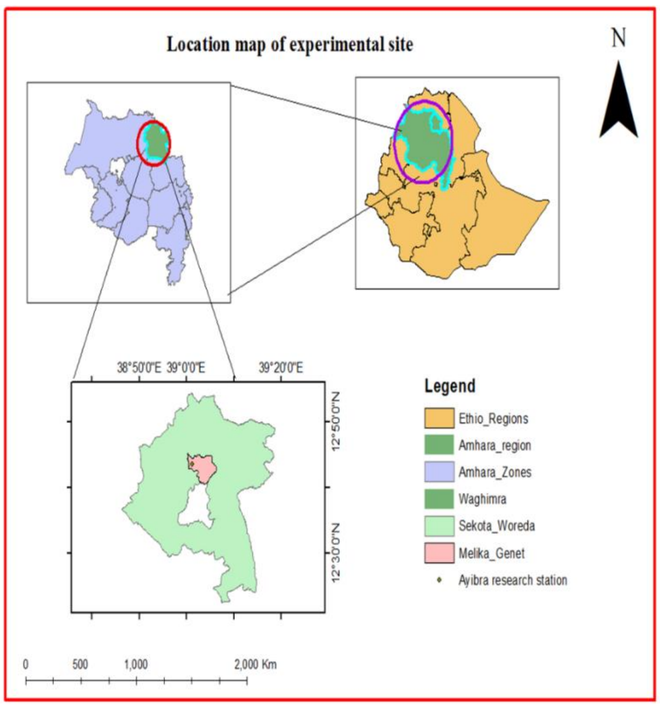

Fig. 1. Location map of the study area

B. Experimental Materials

The study's conducted using sorghum variety called Melkam, which has short maturity period. The variety melkam has been acknowledged and advocated as a high yielding and early maturing crop variety in Wag- Hemira administrative zone [1]. The companion crop mung bean variety Rasa (N-26), which is released by MARC in 2011 and recommended for wag-hemira area.

C. Feld Experimental Treatment, Design and Procedures

Three mung bean seed proportions (200%, 100%, and 67%) and four sorghum-mung bean intercropping row configurations (1S:1M, 2S:1M, 1S:2M, and 3S:1M were conducted in factorial randomized complete block design (RCBD) with three replications in a plots size of 4.5 m length X 4 width (18m2 plot size) and plots to plot were separated with 0.5 m and 1 m between blocks respectively. The seeds of sorghum and mung bean were obtained from the Sekota Dry Land Agricultural Research Centre (SDARC). The seed rate of sorghum were 15 kg ha^{-1} based and the seed rates of mung bean were vary as the mung bean is the treatments and seeds were planted per pit of mung bean, and the plants were thinned to one per hole for the mung bean intercropped and sole plots.

For both solitary sorghum and intercropped sorghum plots, the standard recommendation of 100 kg NPSB and 50 kg urea (46% N) ha^{-1} was employed. The complete dose of NPSB was applied at the time of planting, while half of the nitrogen was top-dressed after the sorghum plant reached knee height, which is typically when it has produced six to eight leaves. A total of 100 kg of NPSB ha^{-1} was applied and distributed uniformly for sole mung bean plots. A solution of Karate chemical (0.4 L of chemical dissolved in 200 L of water ha^{-1}) was immediately applied via spraying upon the emergence of flea beetles (Trirhabda flavolimbta) on the leaves of the mung bean.

TABLE I. List of Treatments and Their Arrangements

Treatment	Sorghum-mung bean row configuration	Mung bean Seed proportions	All over Combination
1	1S:1M	200%	1S:1M X200%
2	2S:1M	200%	2S:1M X200%
3	1S:2M	200%	1S:2M X200%
4	3S:1M	200%	3S:1M X200%
5	1S:1M	100%	1S:1M X100%
6	2S:1M	100%	2S:1MX100%
7	1S:2M	100%	1S:2M X100%
8	3S:1M	100%	3S:1M X100%
9	1S:1M	67%	1S:1M X67%
10	2S:1M	67%	2S:1MX67%
11	1S:2M	67%	1S:2MX67%
12	3S:1M	67%	3S:1MX67%
13	Sole Sorghum	-	Sole Sorghumx100
14	Sole mung bean	100%	Sole mung beanx100

Where S= sorghum and M= mung bean

D. Indices of Intercrop System Productivity and Benefits

1) Land Equivalent Ratio

The criterion for determining the advantage of mixed plantings is the land equivalent ratio (LER). According to [21] it is a measure of complementarity and the value of unity is important. The LER was calculated as follows:

$$LER = \frac{YAB}{YA} + \frac{YBA}{B} \quad \text{...(1)}$$

Where; YAB=yield of crop A (sorghum) when intercropped with crop B (mung bean) YBA=Yield of crop B (mung bean) when intercropped with crop A (sorghum) YA=Yield from sole planted crop A (sorghum) YB=Yield from sole planted crop B (mung bean). When the LER is greater than one, the intercropping favors the growth and yield of the species. In contrast, when LER is lower than one the intercropping negatively affects the growth and yield of the plants grown in mixtures [20] Partial LER of sorghum and the partial LER of mung bean was first calculated to determine the total land equivalent ratio and to determine whether the main crop is benefited with the added crop or not.

2) Land Equivalent Ratio

ATER provides a more realistic comparison of the yield advantage of intercropping over mono- cropping in terms of time taken by component crops in the intercropping systems than LER and it was calculated by a formula developed by [21] and calculated as:

$$ATER = \frac{RYA\ x\ ta + RYB\ x\ tb}{T} \text{ ....(2)}$$

Where YA= relative yield of crop A, ta= the time taken by crop a, RYB= relative yield of crop B, Tb= the time taken by crop B and T= the total time taken by the system and its interpretations is based on the value. If ATER>1, yield advantage, and if ATER < 1, yield disadvantage as well as if ATER =1 one effect or no effect of intercropping.

3) Competitive Ratio (CR)

Competitive ratio (CR) gives more desirable competitive ability for the crops and it is another way to know the degree with which one crop competes more than other for growth resource during intercrop. The CR represents simply the ratio of individual LERs of the two component crops and takes into account the proportion of the crops on which they are initially sown. The CR index is calculated as:

$$CRAB = \left(\frac{LEA}{LERB}\right)\left(\frac{Zlb}{Zab}\right) \text{ ....(3)}$$

While

$$CRBA = \left(\frac{LERBA}{LERB}\right)\left(\frac{Zlb}{Zlba}\right) \text{ ....(4)}$$

Where CRAB= competitive ration of crop A (sorghum) on crop B (mung bean), LEA= land equivalent ration of crop A (partial land equivalent of crop A), LEB= land equivalent ratio of crop B, ZIb=sowing proportion of crop B (mung bean), Zab= sowing proportion of crop A (sorghum). If CR > one, indicates the base crop is competitor, while values < one implies the minor component crop is profusely suppressed the base crop or if CR cereal = 0, both crops are equally competitive, if CR cereal is positive then the cereal species is dominant, if CR cereal is negative then the cereal species is the dominated species.

4) Monetary advantage index (MAI)

It was also calculated to give some economic evaluation of intercropping as compared to sole cropping. The monetary advantage index (MAI) was calculated by the formula developed by [20 and 21].

$$MAI = The\ value\ of\ the\ intercorp\ x\ \frac{(LER-1)}{LER} \text{ ....(5)}$$

The positive value of MAI indicates visibility of the system. As the time changes, the price of the two crops also changes. Due to this, the prices was at the time of harvesting, particularly November. The price of sorghum and mung bean at the time of harvesting was 50 and 70 birr per kg on the local market at Aybra, sekota district (Personal observation and SWAO, 2023).

E. Partial Budget Analysis

Prior to partial budget analysis, the actual biomass and grain yield was adjusted downward by 10% to equalize the experimental yields with farmers would expect to get from the same treatment. For each treatments the gross benefit (GB), total costs that vary (TCV), net benefit (NB), and the marginal rate of return (MRR) was analyzed separately. Gross benefit was calculated as the product of adjusted grain and stalk yields and the price per kilogram of grain and stalk of sorghum and the grain yield of mung bean with respective price in each treatment. The current price of 1 kg of sorghum grain and stalk were 50 and 5 ETB, respectively, whereas the price of 1 kg of mung bean was 70 birr. The total costs that varied among all the treatments were fertilizer purchase costs, labor cost, chemical cost, and seed costs in ETB ha-1. All the cost was valued based on the current price of each items. The cost of fertilizer in the form of urea and NPS was 45 birr per kg, the cost of labor per day was 200 birr and the chemical cost per litter was 2200 birr. The Net benefits (NB) was calculated as the difference between the gross benefit (GB) and total variable cost (TVC) of each treatment in ETB ha-1. The dominance analyses were carried out first by listing the treatments in increasing cost variation for identifies the economically preferable treatment. The dominated treatments were removed from the analysis of MRR (CIMMYT, 1988). For each pair of ranked treatments, a marginal rate of return (MRR) was calculated change in net benefit to change in total variable cost as:

$$\text{MRR} = NB/TVC * 100 \text{ ....(6)}$$

The MRR% between any pair of non-dominated treatments denotes the return per row arrangement and seed. The recommendation of this research was supported by economic analysis for significant biological yields, which is the partial budget analysis based on (CIMMYT, 1988)

F. Data Analysis

Quantitative data of the component crops from the experimental field was entered into Microsoft office excel. Data analyses for the growth, yield, and yield component of the component crops were conducted using statistical Software (SAS, 2016). Before analysis, the data were checked for normal distribution following the Shapiro-Wilk test for normality. Data were analyzed with mung bean seed proportions and spatial sorghum-mung bean arrangement as fixed effects and replication as random effects. When there were significant differences between treatments at any5and 1% probability level, mean separation was done using the Tukey-Kramer HSD test. However, if there was no significant difference (P > 0.05) between all treatments (14), the data analysis of the same data in 12 treatments (excluding the sole crops) was subjected to an analysis of variance (ANOVA) following normal procedure. Mean separation was done using the same test, when there were significant differences between treatments at any probability level difference (P < 0.05).

III. Results and Discussion

The analysis of variance presented in table 2 demonstrates (showes) the existence of significant differences among the treatments and the intercrop indices. This suggests the chance for calculating the intercrop indices and the economic feasibility of the intercrop system among the treatments, as well as importance of identifying the optimal seed proportions of mung bean and the best planting pattern (row ratio) of sorghum-mung bean intercrop for the study area.

TABLE II. MEAN SQUARE VALUE OF SORGHUM MUNG BEAN ROW ARRANGEMENT AND SEED PROPORTIONS OF MUNG BEAN ON SOME INTERCROP INDEXES

Treatments	DF	PLER Sor	PLER Mg	TLER	ATER	MAI	CR Sor	CR mg	CR total
RA	3	0.08**	0.034**	0.106**	0.15**	5.2e+07**	0.27**	0.023**	3.66**
SPP	2	0.002ns	0.47**	0.065**	0.016**	8.5e+08**	0.08**	0.039**	13.59**
RA X SPP	6	0.027**	0.33**	0.110**	0.06**	2.5e+09**	0.22**	0.045**	14.29**
Error	22	0.001	0.004	0.01	0.0021	7.8e+07	0.005	0.003	0.66
Total	35								

Where RA= row arrangement of sorghum mung bean intercrop, Spp= seed proportions of mung bean, Df=degree of freedom, PLER Sor= partial land equivalent ratio of sorghum, PLERMg= partial land equivalent ratio of mung bean, TLER= total land equivalent ratio ratio, ATER= area time equivalent ratio, MAI=monetary advantage index, CR Sor= competitive ratio of sorghum, CR Mg= competitive ratio of mung bean

A. System Productivity of Intercropping

1) Partial and Total Land Equivalent Ratio (LER)

Partial LER of sorghum and mung bean were significantly (P<0.05) affected by seed proportion (population density) of mung bean and spatial row difference in sorghum-mung bean intercroping (Table 2). The maximum partial LER of sorghum (0.95) was found when 67% seed proportion of mung bean intercrop at 1S:1M sorghum-mung bean row arrangement flowed through 200% seed proportion of mung bean intercrop with 1S:1M sorghum-mung bean row configuration (0.89) (Table 3). While in terms of PLER of mung bean, the highest (0.55) partial LER were found when 67% seed proportion of mung bean intercrop with sorghum at 1S:2M, while the lowest (0.195) were found in 200% of mung bean intercrop with 1S:2M row configuration. As we compare the partial LER of the two combined crops, partial LER of sorghum was higher than partial LER of mung bean and indicates that sorghum was the main contributor to the mixture yield advantage as well as the main crop was beneficiary of the component crop. Similarly, higher partial LER of cereals than legumes under different row arrangements and seed proportions of cereal-legume intercrops have been reported by [22] [18], and [6].

The total LER for all the combinations, except 3S:1M X 200% of mung bean seed proportion were greater than one but the magnitudes vary from pattern to pattern. The maximum total LER (1.39) was recorded when 100%, 200% and 67% seed proportion of mung bean intercrop with sorghum with 1S:1M flowed by 2S:1M (1.32), 1S:1M X, (1.31) and 1S:2M (1.299) row arrangement and seed proportion of mung bean (Table 3). A total LER 1.39, 1.31, 1.32, and 1.299 indicates that 29-39% additional land was required to produce the same yield as intercropped (to equal with the yield of intercropping system) or the farmers save 39-29% land because of inter cropping in the test location. Similarly to these, reported that 60- 99% land saved due to inter crop in maize- common bean intercrop, [22] report 76% land saved due to intercrop in maize-mung bean intercrop. In line with this finding, [10], [23], [6] and [18] reported higher total LER in 1:1 cereal legume intercrop combinations.

2) Area time equivalent Ratio (ATER)

The lowest (0.78) ATER value was found in the combinations of 3S:1M sorghum-mung bean row arrangement with 67% seed proportion of mung bean and the highest ATER were found (1.6) in 2S:1M sorghum-mung bean row arrangement with 100% seed proportion of mung bean flowed through 1S:1M X100% spatial row arrangement of sorghum-mung bean and seed proportion of mung bean respectively (Table 3). In most of the treatments combinations, ATER values were greater than one indicating the proper resource utilization due to the high variations in the maturity periods of the crops in which sorghum stayed longer on the land and had enough time to fully mature and indicated that sorghum-mung bean intercropping is more advantages in the experimental site

3) Monitory advantage index (MAI)

The value of MAI was significantly (p<0.05) affected by spatial row arrangement of sorghum-mung bean intercrop and seed proportions of mung bean (Table 2) and it ranged from (-34266 ETB ha^{-1}) to (57119 ETB ha^{-1}). The highest economic benefit in terms of MAI (57119 ETB ha^{-1}) was obtained when 67% seed proportion of mung bean intercropped at in 1S:1M flowed through 100% seed proportion of mung bean intercropped at 2S:1M, and 1S: 2M row arrangement of sorghum-mung bean and seed proportions of mung bean respectively and the lowest (-34266 ETB ha^{-1}) were found when 67% seed proportion of mung bean intercrop at 3S:1M row arrangement of sorghum-mung bean intercrop. This may indicate that lowest seed proportions and lowest row arrangement may affect the economic visibility of the system. In most of the treatments included in the study, MAI was positive and negative only in three of the treatments (3S:1M X 67%, 1S:2M X 200%, 1S:2M X 100%, and 3S:1M X 200%). This indicated that planting sorghum with mung bean in such row arrangement combined with such seed proportions of mung bean is not more economically feasible at the tested location as they also have the lowest TLER. The MAI for sole sorghum and mung bean was negative (Table 3) in sign indicates that planting each component crops are not economically reasonable in the area. A similarly reported to this findings was done by [6], [23],] 24], and [18].

4) Competitive Ratio (CR)

The analysis of variance presented in Table 2 indicates that CR was significantly (P < 0.05) affected by the interaction of spatial row arrangement and seed proration. The highest (6.44) value were obtained in 3S:1M X 67% seed proportions of mung bean and lowest (1.14) CR in 1S:1M X 67% than 200% and 100% seed proportions of mung bean. The CR value of sorghum was higher than the CR value of mung bean (Table 4) and indicated that sorghum was more competitive than mung bean in sorghum-mung bean intercropping and the CR value were higher than unity indicating that intercropping of sorghum with mung bean in the study area is productive than planting each alone. In line with to this findings, [6] reported that maize was more competitive than mung bean in maize-mung bean intercropping. [25], reported that tef had higher CR value than lupin in tef-lupin intercrop and [19] reported that

CR value of sunflower was higher than mung bean in mung bean-sunflower intercrop.

TABLE III. PARTIAL AND TOTAL LAND EQUIVALENT, AREA TIME EQUIVALENT, AND MONETARY ADVANTAGE OF SORGHUM-MUNG BEAN ROW ARRANGEMENT AND SEED PROPORTIONS OF MUNG BEAN

Treatments	**PLE Sor**	**PLER Mg**	**TLE R**	**ATE R**	**MAI**
1S:1 MX200%	0.89^{ab}	0.41^{b}	1.31^{a}	1.20^{ab}	47328^{a}
1S:1M X100%	0.78^{cd}	0.33^{c}	1.27^{b}	1.03^{c}	20848^{b}
1S:1M X67%	0.95^{a}	0.44^{b}	1.39^{a}	1.28^{a}	57119^{a}
2S:1M X200%	0.81^{c}	0.33^{c}	1.14^{b}	1.05^{c}	24404^{b}
2S:1M X100%	0.87^{b}	0.44^{b}	1.32^{a}	1.20^{ab}	48971^{a}
2S:1 MX67%	0.66^{ef}	0.51^{a}	1.18^{b}	1.04^{c}	31938^{b}
1S:2M X200%	0.64^{ef}	0.30^{c}	0.95^{c}	0.87^{d}	-9555^{c}
1S:2M X100%	0.76^{cd}	0.35^{c}	1.11^{b}	1.02^{c}	19163^{b}
1S:2M X67%	0.61^{f}	0.23^{d}	0.84^{d}	0.78^{e}	-34266^{e}
3S:1M X200%	0.68^{e}	0.19^{d}	0.87^{cd}	0.82^{de}	-25660de
3S:1M X100%	0.63^{ef}	0.30^{c}	0.94^{c}	0.86^{ed}	-11528^{cd}
3S:1M X67%	0.74^{d}	0.55^{a}	1.29^{a}	1.15^{b}	48618^{a}
13 Sole sorghum	0.75^{d}	-	0.75^{ed}	-	-52007.7^{f}
14 Sole mung bean	-	0.37^{c}	0.37^{f}	-	-155639.75^{g}
Mean	0.75	0.37	1.13	1.03	18115
HSD (5%).	**	**	**	**	**
C.V (%)	4.6	8.69	4.73	4.57	31.53
R2	0.93	0.93	0.94	0.94	0.94

Where S, sorghum PLER Sor=partial land equivalent of sorghum, PLERMg= partial land equivalent of mung bean, TLER=total land equivalent ratio, ATER=Area time equivalent ratio, MAI, Monetary advantage index, LSD= least significance differences, CV= coefficient of variation, **= significance at 1%level of probability

TABLE IV. INTERACTION EFFECT OF SORGHUM MUNG BEAN ROW ARRANGEMENT AND SEED PROPORTIONS OF MUNG BEAN ON COMPETITIVE RATIO

Treatments	**CR Sor**	**CR Mg**	**CR total**
1S:1M X200%	0.87^{cd}	0.44^{b}	1.94^{cd}
1S:1 XM100%	1.01^{bc}	0.26^{defg}	3.87^{b}
1S:1 XM67%	1.46^{a}	0.23^{efg}	6.17^{a}
2S:1 XM200%	1.00^{bc}	0.27^{def}	3.71^{b}
2S:1 XM100%	0.88^{cd}	0.43^{b}	2.01^{cd}
2S:1 XM67%	0.86^{d}	0.40^{bc}	2.15^{cd}
1S:2 XM200%	1.03^{b}	0.16^{g}	6.46^{a}
1S:2 XM100%	0.87^{cd}	0.3^{cdef}	2.86^{bc}
1S:2 XM67%	0.46^{f}	0.33^{cde}	1.42^{cd}
3S:1 XM200%	0.99^{bcd}	0.2f^{g}	5.82^{a}
3S:1 XM100%	0.51^{f}	0.36^{bcd}	1.54^{cd}
3S:1 XM67%	0.63^{e}	0.56^{a}	1.14^{d}
Mean	0.88	0.33	3.26
HSD (5%).	**	**	**
C.V (%)	8.4	16.86	25.07
R2	0.94	0.85	0.88

Where S= sorghum, M= mung bean, CR sor=Competitive ration of sorghum, CRMg= Competitive ration of mung bean, Agg Sor= aggressivity of sorghum, Agg Mg=aggressivity of mung bean, LSD= least significance differences, CV= coefficient of variation, **= significance at 1% level of probability

B. *Economic Analysis of the Component Crop (Partial budget analysis)*

The maximum net benefit (207537.9) was recorded when 200% seed rate of mung bean intercrop in 1S:1M row arrangement followed by 100% seed rate of mung bean (187266.9) intercrop in 1S:1M row arrangement with MRR of 2094.20 and 595.30% respectively, whereas the sole mung bean treatment produced the lowest net benefit (75152.3 ETB) ha-1. (Table 5). The lowest net benefit was recorded from 67% seed rate of mung bean planted in 2S:1M row arrangement.

TABLE V. ECONOMIC (NET BENEFIT) ADVANTAGE OF SORGHUM-MUNG BEAN INTERCROP THAN PLANTING EACH ALONE

RA	SPP	GSBM	GSGY	GMY	TVCC	ABM	ASGY	AMY	GB	NEB	D	MRR
Sole Mg	100%	-	-	1307.18	7200	0	0	1176.462	82352.34	75152.34		
Sole Sor	100%	7978	3218.105	0	7290	7180.02	2896.295	0	180714.8	173424.8		109191.7
3S:1M	67%	6066	2397	255.46	8259.43	5459.04	2157.12	229.914	151245.2	142985.8	D	
3S:1M	100%	6399	2146	269.05	8365.2	5759.01	1931.49	242.145	142319.7	133954.5	D	
2S:1M	67%	4954	2174	301.85	8610.982	4458.96	1956.6	271.665	139141.4	130530.4	D	
3S:1M	200%	6399	2187	401.11	8685.52	5759.01	1968.66	360.999	152498	143812.5	D	
2S:M1	100%	6868	2828	457.64	8804.28	6181.02	2545.47	411.876	187009.9	178205.6		315.7154
2S:1M	200%	5294	2641	558.57	9284.606	4764.42	2376.9	502.713	177857	168572.4	D	
1S:1M	67%	7754	2542	441.44	10006.36	6978.96	2287.44	397.296	177077.5	167071.2	D	
1S:1M	100%	7840	2895	508.33	10326.4	7056	2605.77	457.497	197593.3	187266.9		595.3046
1S:1M	200%	8510	3112	642.6	11294.36	7659	2801.07	578.34	218832.3	207537.9		2094.203
1S:2M	67%	6529	2168	676.16	12373.7	5876.01	1951.2	608.544	169538.1	157164.4	D	
1S:2M	100%	6066	2455	578.7	13362.52	5459.04	2209.86	520.83	174246.3	160883.8	D	
1S:2M	200%	5064	2071	919.95	15299.28	4557.96	1864.26	827.955	173959.7	158660.4	D	

Where Mg= sole mung bean, Sor= sole sorghum, GSBM= gross sorghum biomass, GSGY=gross sorghum yield, GMV,=gross mung bean, TVC=total variable cost, ABM=adjusted biomass of sorghum, ASGY= adjusted grain yield of sorghum, AMY=adjusted mung bean yield, GB=gross benefit, NEB=net benefit, D= dominance, and MRR= marginal revenue of return

IV. CONCLUSIONS AND RECOMMENDATIONS

Cereal-legume intercropping is particularly important for sustainable crop production systems, especially in situations where farmers use little or no fertilizer and fragment land size. To optimize the efficiency of intercrop production, it is essential to identify the optimal seed proportions and the most suitable row configuration of the intercropping system. The highest (1.39, 1.32, and 1.31) total LER of intercropping was calculated when 67, 100, and 200% seed proportion of mung bean intercropping at 1:1 and 2:1 spatial row arrangement. Intercropping of sorghum with mung bean can save 31-39% land in addition to produces the same yield and it indicates efficient resource utilization in the study area. The highest positive monetary advantage index (57119 and 47328 ETB ha-1) obtained when a 67% and 200% seed proportion of mung bean was intercrop with sorghum at a 1:1 spatial arrangement. The highest marginal rate of return (2094.203) was obtained from when 200% seed proportion of mung bean intercrop with 1:1 row configuration while the lowest net benefit (315.7154) was obtained when 100% seed proportion of mung bean intercrop at 2S:1M row arrangement. Thus, it can be concluded that planting mung bean with 200% seed proportion with sorghum at a 1S:1M spatial arrangement increased the output and profitability of the sorghum-mung bean intercrop. The overall result of this research findings indicated that, intercropping of mung bean with sorghum in the study area is productive in terms of land and economy than solitary planting of each crops. Therefore, planting sorghum with mung bean in 1:1 planting patterns with 67% and 200% seed proportions of mung bean are recommended to intercropping sorghum with mung bean in wag-hemria and similar agro-ecology.

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