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Effect of Seed Rate and Row Spacing on Yield and Yield Components of Rain Fed Upland Rice (*Oryza sativa* L.) Variety in Pawe Northwestern Ethiopia

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Abstract

An experiment was conducted at Pawe during the rainy seasons of 2018 and 2019 cropping season. The objectives of the experiment was to determine the effect of row spacing (RS) and seed rate (SR) on yield and yield components of upland rice, and to determine economically feasible seed rate and row spacing for upland rice producing farmers in Pawe areas. Factorial combination of Four row spacing (15, 20, 25 and 30 cm) and seven level of seed rates (40, 60, 80, 100, 120,140 and 160 kg ha^{-1}) were laid in RCB design with three replications. All collected data's' were subjected to analysis of variance using SAS software. The economic analysis was done consider the grain and straw yield. The analysis of variance showed that, the biomass yield, grain yield and straw yield ha^{-1} were significantly ($P<0.05$) and total tillers per 0.5m row length was highly significantly ($P<0.01$) affected by Row spacing. Main effect of seed rate also highly significantly ($P<0.01$) affected the plant height, total tillers per 0.5m row length, fertile grains per panicle, above ground biomass yield ha^{-1}, grain yield ha^{-1}and straw yield ha^{-1}, and significantly ($P<0.05$) affected un-effective grain per panicle. Interaction effect of RS and SR was significant in harvesting index, but others agronomic parameters were not significant different. The highest grain yield (3695.35 kg ha^{-1}) was obtained from seed rate of 80 kg ha^{-1}. The economic analysis indicated that 80 kg ha^{-1}SR is most profitable with NB (42892.8Birr ha^{-1}). Depend on row spacing, 20 cm was higher NB, but not more significant compared to 30 cm and not easily applicable for users. Therefore, 30cm row spacing with 80 kg ha^{-1} seed rate is acceptable and recommended for upland rice production system in Pawe areas and similar agro ecologies.

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Keywords

Net benefit, Row spacing, Seed rate, Yield, Upland rice.

Introduction

Rice (*Oryza sativa* L.) is recent cultivated generally considered a semiaquatic annual grass, although in the tropics it can survive as perennial producing new tillers from nodes after harvest (ratooning). It is now a strategic commodity for food security in Africa that is more than 75 million peoples in sub-Saharan Africa (SSA) consume rice crop (Roy-Macauley, 2019) and considered as a major source of calories for more than half of the global population (Carrijo *et al.*, 2017). Rice productivity and profitability plan is implemented through four cross cutting continental rice research and development programs that is genetic diversity and improvement; sustainable productivity enhancement; policy, innovation systems and impact assessment; and rice sector development (Carrijo *et al.*, 2017). The plans continuous to deliver research products and services, which are relevant to developing the rice sector in countries. Rice constitutes a single most important source of deity energy in West Africa and the third most important staple food crop for the whole of sub-Saharan Africa. Average per capital consumption across SSA is about 40 kg per year, while with large variation among countries, reaching over 140 kg per annum in Madagascar (Abdelbagi, 2019).

In most countries including Ethiopia, traditional production, post-harvest and processing systems still persist leading to low revenues for farmers because of labor costs and poor quality of their produce. Rain fed farming predominate covering about 75% of the rice area, with unreliable water resources and prevalence of several abiotic stresses including drought, floods and soil problems (Dawit, 2019). But rice has several advantages over other cereals in Ethiopia, higher yields and suitability for preparation of several national dishes, together with availability of natural resources for significant expansion. Report indicated the country has estimated area of 30 million ha (5.6 million highly suitable and 25 million suitable) for rain fed rice production and 3.7 million ha of lands are suitable for irrigated rice. From this North West low land areas of Amhara and Benshangul gumuze regions mainly Jawi, Pawe and Dangur districts are rice producing areas (Dawit, 2015).

Proper agronomic and crop management strategies need to be in place to narrow the current and future gaps between attainable yields and farmers yields of rice (Nhamo *et al.*, 2014). These gaps are considerably wide in SSA and can reach 40% in some countries. Management principles should be geared towards maximizing the potential of the new varieties and maintain their performance within efficient and sustainable production systems that optimize resource use and augment farmers revenues.

Rate of crop establishment has a great impact on plant density, tillering, time to maturity and yield (*Das et al.*, 2020). Among many factors, seed rate and row spacing influence the grain yield of aerobic rice crop (Jana *et al.*, 2016).The optimum plant population per unit area is a major yield determining factor, so optimum seeding rate is essential for the better performance of wet seeded rice (Anisuzzaman *et al.*, 2010). Lower and higher plant densities have a positive influence on the yield of rice. Higher seeding rate (35 kg ha^{-1}) is one approach that helps in increasing crop competitiveness against weeds that facilitate quick canopy closure, which helps suppress weeds more effectively. But at low seeding rate (25 kg ha) rice crop plants take more time to close their canopy which encourages the weed growth (Jana *et al.*, 2016).

Spacing is dependent on ecology, species and genotypic characteristics of varieties. So determination of the optimum plant population per unit area and spacing is necessary to obtaining high rice yield (Rasool *et al.*, 2013). Un-appropriate plant spacing reduces the yield of rice up to 25-30 percent (IRRI, 1993). Optimum plant spacing ensures plants to grow properly both in their above and underground parts through different utilization of below and above ground resources such as solar radiation and nutrients (Mohaddesi *et al.*, 2011).Total and effective tillers significantly affected by row spacing (Martin *et al.*, 2010) and high seeding rate leads to non-productive tillers, more severe disease pressure and susceptible to lodging (Garba *et al.*, 2018). Information of optimum seed rates with varying levels of row spacing for maximizing grain yield of upland rice (Jana, 2018). Sufficient information regarding their optimum planting density under different agro-climatic condition like Pawe has not been generated so far. Therefore the objective of the present study was to determine the effect of row spacing and seed rate on yield and yield components of rice in the areas.

Materials and Methods

Description of the Study Area

The experiment was conducted at Pawe areas located in the lowlands of the northwestern part of Ethiopia. The geographical location is between 11^{0} 15′ North latitude and 36^{0}30′ East longitudes. The topography is slightly undulating from 1100-1200 m.a.s.l. The area has a univocal rainfall pattern that extends from May to October with mean annual rainfall above 1500 mm per year. The mean annual maximum and minimum temperature is 32.6 ^{0}C and 16.5 ^{0}C, respectively which is a hot humid environment. The soils are broadly categorized as *Vertisoils*, *Nitisols* and intermediate soils of Luvisols (blackish brown color) which are more suitable for rice production.

Treatments and Experimental Design

The experiment had a combination of four row spacing (15, 20, 25 and 30 cm) and seven seeding rate (40, 60, 80, 100, 120,140 and 160 kg ha^{-1}) laid out RCBD in factorial arrangement which replicated three times. The plot size was 3m by 3 m (9 m^2) and the net plot size was made by excluding the left and right two outer rows of the plot area. The variety NERICA-4 was used for this experiment. The recommended fertilizer was 100 kg TSP and 100 kg urea used as a blanket recommendation for Pawe District.

Experimental Procedure and Field Management

The experimental field plots were ploughed two times using tractor mounted disc plough to 30 cm soil depth on station and oxen ploughed on farmer's field. Seeding was done by hand drilling using the recommended seed rate ha^{-1}. All agronomic field management practices were done as required. N fertilizer was applied in three equal splits viz., one-third at planting, one-third at tillering (at 3-4 tillering stage) and remaining one-third at panicle initiation. Application of phosphorus fertilizer (46% P2O5) and the initial N fertilizer rate was at sowing.

Data to be collected

Data's such as plant height, panicle length, fertile grain and non-fertile grain per panicle were collected from ten randomly selected plants from net plot area and averaged it. Number of total tillers and effective tillers per 0.5 m row meter length were collected from 5 randomly selected rows of the net plot areas and averaged it. Above ground dry biomass yield per hectare (ABY kg ha^{-1}) was harvested from the net plot, sun dried for 72 hours and measured in kg and then converted in hectare.

Thousand kernel weight (TKW) was recorded in gram with sensitive balance which was taken from bulked grains of each plot and adjusted to 14% seed moisture level. Grain yield per hectare (GY kg ha^{-1}) was measured from net plot of each plot and converted to kilograms per hectare at 14% moisture content. Harvest index (%) was calculated with the formula;

$$Harvest\ index = \frac{Grain\ yield}{Biomass\ yield} \times 100$$

Statistical Data Analyses

All collected data were subjected to analysis of variance (ANOVA) using SAS software version 9.3 (SAS-Institute, 2014). Combined analysis over locations and years was performed. Between treatments, comparisons of means were made using the Least Significant Difference (LSD) test at 1 and 5% probability levels.

The partial budget analysis was done as described by CIMMYT (1988) rules where the variable cost included the cost of seeds and planting. The prevailing cost of inputs and out puts in year 2020 considered for the analysis. The Paddy grain and straw yields were subjected to partial budget analysis. Net benefit was calculated as the amount of money left when the total variable costs for inputs (TVC) are deducted from the Gross benefit (GR). The yield was adjusted downward by 10% before calculating the gross return to have an idea of how much benefit can be obtained based on variable cost. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment is dominated treatment (marked as "**D**"). The Marginal rate of return (MRR) 100% is used to assess relative profitability among alternative treatments. The cost of rice grain and straw were Birr 13.5 and 1200 per ton, respectively. A treatment which is non-dominated and having the highest net benefit is said to be economically profitable.

Results and Discussion

Plant Height and total tillers

The analysis of variance indicated that, plant height was highly significant ($P \leq 0.01$) affected by seeding rate, but not significantly ($P \leq 0.05$) affected by row spacing (RS) and interaction of SR and RS) (Table 1).

The tallest (72.988 cm) and the shortest (67.879 cm) plant were obtained from 40 kg ha^{-1} and 160 kg SR, respectively. These finding indicated higher seed rate might be produce higher number of plant population in areas which performs more intra row computation of available resources and nutrients resulted in shortage of plant height. Garba *et al.*, (2018) indicated, seed rate increased from 32-75 kg ha-1 plant height and number of tillers numerically increased. Sultan *et al.*, (2020) reported not similar that the maximum plant height at 60 DAS (88.67 cm), 90 DAS (112.82 cm) and harvest (112.92 cm) with 120 kg ha^{-1} seed rate as compared to the lower seed rate. The result of Abaynew *et al.*, (2020) showed that plant height was highly significantly ($p<0.01$) affected by main effects of seeding rate.

Total tillers per 0.5 m row length also highly significant ($P \leq 0.01$) on both RS and SR ha^{-1}, but its interaction was not significant (Table 1). The highest (46.81) and lowest (35.90) number of total tillers per 0.5 meter row length was observed at RS 30cm and 15cm respectively. This might be due to the narrow row spacing increases the number of rows per area in space and the seed distribution minimized than the wider row spacing. In other, in wider row spacing no more inter row competition of resources; the plant easily increase tillering capacity. So, the number of plant population increased with wider row spacing compared to the narrow one. Zewdineh and Yalew, (2020) indicated similar result that the highest tillers per 0.5 m row length was observed at 25 and 30 cm row length with 96 kg N ha^{-1}, but the lowest was at 20 cm. Garba *et al.,* (2018) also reported the maximum number of tillers were recorded from 25*25 cm row spacing as compared to the lower row spacing and broadcast planting method. The maximum (65.5) and minimum (54.8) number of total tillers per row meter length was recorded from 30 cm and 15 cm row spacing, respectively (Zelalem *et al.,* 2019). On the hard the highest (48.417) and lowest (34.826) number of total tillers per 0.5 m row length observed at seed rate of 140 kg $ha^{-1}$and 40 kg ha^{-1} respectively. The result was in line with Zelalem *et al.,* (2019) and Abaynew *et al.,* (2020) that both numbers of total and effective tillers per row length were highly affected by seed rate. When the seed rate was increased from 60 to 140, the number of effective tillers increased as well. The maximum number of total tillers per row meter length (66.5) and the minimum (56.3) were recorded from the seed rate of 140 kg ha^{-1}, respectively (Zelalem *et al.,* 2019).

Fertile grain per panicle

The statistical analysis of variance indicated fertile grain per panicle was highly significant ($p \leq 0.01$) while unfertile grain was significantly ($p \leq 0.05$) affected by main effect of SR (Table 1). The highest number of fertile grain per panicle (91.628) was recorded on 30 cm row spacing, but at par with 20 and 25 cm row spacing. The lowest number of fertile grain per panicle (85.828) was recorded from 15 cm row spacing. This might be due to inter-row competition of resources affects the sink distribution on individual seed filling at panicle growth stage. But, Zelalem *et al.,* (2020) reported that fertile grain wasn't significantly affected by row spacing and seed rate. On the other hand, the 60 kilogram seed rate per hectare yielded the most un-effective grain per panicle, but it was comparable to 40 kg and 160 kg seeding rates. Number of filled grains per panicle exhibited that, it was highly significantly ($p<0.01$) influenced by main effect of inter-row spacing and seeding rate. Maximum number of filled grains per panicle (97.76) was recorded from seeding rate of 40 kg ha^{-1} and the minimum one was 160 kg ha^{-1} (Abaynew *et al.,* 2020).

Above Ground Biomass and Grain Yield per hector

The result indicated that biomass and grain yield was significantly ($p \leq 0.05$) affected by main effect of row spacing; and biomass yield was highly significant ($p \leq 0.01$) affected by main effect of seeding rate per ha^{-1}. But, interaction of RS*SR was not significant on both biomass and grain yield.

The highest number of biomass yield (7,950.3 kg ha^{-1}) was recorded from 20 cm row spacing, but at par with 15 cm row spacing. Depend on seed rate, the highest biomass yield (8001.1 kg ha^{-1}) was recorded by 120 kg ha^{-1}, but comparable to 80 kg, 140 kg and 160 kg ha^{-1} and the lowest biomass yield was 40 kg ha^{-1}

The maximum grain yield (3634.36 kg ha^{-1}) was recorded by 20 cm, but at par with 15 cm row spacing and the lowest one was 25 cm row spacing. Similar result was indicated by Zewdineh and Yalew (2020), the highest biomass and grain yield was found from 20 cm row spacing, but at par with 25 and 30 cm row spacing. The highest grain yield (3695.35 kg ha^{-1}) was recorded by 80 kg and comparable to120 kg ha^{-1}, while the lowest one was recorded on 40 kg ha^{-1}.Similar output was observed by Zelalem *et al.,* (2019) that main effect of seed rate and row spacing had highly significant effect on grain yield in low land rice. Abaynew *et al.,* (2020) reported that 25 cm row spacing had given the highest net benefit with acceptable range of marginal rate of return. Application of 100 kg ha^{-1} seeding rate and 25 cm inter-row spacing is economically feasible and can be recommended for users.

Garba *et al.,* (2018) also indicated grain yield increased when seed rate 54 kg compared to 32 and 75 kg ha^{-1}.Line sowing of CAU-R1 at the seed rate of 100 kg ha^{-1}has recorded the highest grain $yield^{-1}$(6030.11 kg ha) and with the decrease or increase in seed rate, the grain yield was also reduced (Susmita *et al.,* 2020).Grain yield increased with increase in seed rate up to 30 kg ha^{-1}, then yield decreased with increase in seed rate at 35 kg ha and this might be due to higher plant population per unit area. Decreased in grain yield may be due to increase in competition among the rice plants for water, nutrients, air and light etc., which mutual shading resulted in weaker plants and ultimately produced lower grain yield, when used the higher seed rate (Jana *et al.,* 2016).

Table.1 Effect of Seed Rates and Row Spacing on Yield and Yield Components of Rain Fed up-land Rice (*Oryza sativa* L.) Variety

RS	PH	TT/0.5m	PL	FG	UFG	BYH	GYH	HI	TKW	STY
15 cm	70.05	35.90^{d}	17.81	85.828^{b}	3.756	7734.7^{a}b	3518.46^{ab}	45.59	26.452	4216.22^{ab}
20 cm	70.55	39.22^{c}	17.63	91.37^{a}	4.142	7950.3^{a}	3634.37a	45.81	26.133	4315.91^{a}
25 cm	69.83	42.52^{b}	17.87	88.019^{ab}	3.992	7555.3^{b}	3466.4^{b}	46.07	26.301	4088.86^{b}
30 cm	70.95	46.81^{a}	17.87	91.628^{a}	3.999	7662.5^{b}	3511.33^{b}	45.63	26.141	4177.81^{ab}
LSD (5%)	**NS**	**2.02**	**NS**	**5.514**	**NS**	**240.5**	**120.22**	**NS**	**NS**	**139.5**
Seed rate (kg/ha)										
40	72.99^{a}	34.83^{d}	18.44	103.849^{a}	4.379^{ab}	7140.8^{c}	3373.99^{c}	47.29^{a}	26.6	3766.81^{d}
60	71.13^{b}	36.38^{d}	18.07	97.332^{a}	4.698^{a}	7640.7^{b}	3531.18^{ab}	46.28^{bc}	26.26	4081.07^{c}
80	70.54^{bc}	39.74^{c}	17.76	87.769^{b}	3.848^{bcd}	7764.8^{ab}	3695.35^{a}	46.91^{ab}	26.14	4144.48^{c}
100	70.25^{bc}	40.52^{c}	17.6	85.123^{b}	3.793^{bcd}	7669.1^{b}	3466.38^{bc}	45.35^{de}	26.24	4202.77^{bc}
120	70.35^{bc}	43.74^{b}	17.97	85.202^{b}	3.293^{d}	8001.1^{a}	3643.95^{a}	45.73^{cd}	26.14	4357.19^{ab}
140	69.27^{cd}	48.42^{a}	17.48	83.147^{b}	3.581^{cd}	7910.9^{ab}	3534.48^{ab}	44.88^{e}	26.34	4376.39^{ab}
160	67.879^{d}	44.16^{b}	17.25	82.056^{b}	4.213^{abc}	7952.3^{ab}	3483.11^{bc}	44.003^{f}	26.08	4469.21^{a}
LSD (5%)	**1.7268**	**2.6746**	**NS**	**7.2961**	**0.6475**	**318.15**	**159.04**	**0.7995**	**NS**	**184.5**

Table.2 Economic analysis for grain and straw yield for main effects of seed rate, row spacing and their interaction of upland rice at Pawe

Row Spacing	GYH	STY	AGYH	ASYH	GB	TVC	NB	MRR (%)
30 cm	3511.33	4177.81	3160.2	3760.03	42058.4	1000	41058.4	-
25 cm	3466.4	4088.86	3119.76	3679.97	41485.1	1400	40085.1	D
20 cm	3634.37	4315.91	3270.93	3884.32	43523.9	1750	41773.9	95.41
15 cm	3518.46	4216.22	3166.61	3794.6	42173.4	2100	40073.4	D
Seed rate (kg/ha)								
40	3373.99	3766.81	3036.59	3390.13	40168.2	560	39608.2	-
60	3531.18	4081.07	3178.06	3672.96	42177	840	41337	617.42
80	3695.35	4144.48	3325.82	3730.03	44012.8	1120	42892.8	555.65
100	3466.38	4202.77	3119.74	3782.49	41597.6	1400	40197.6	D
120	3643.95	4357.19	3279.56	3921.47	43668.3	1680	41988.3	D
140	3534.48	4376.39	3181.03	3938.75	42505	1960	40545	D
160	3483.11	4469.21	3134.8	4022.29	42042.1	2240	39802.1	D

GYH=grain yield ha^{-1}; STYH= straw yield; AGYH & ASTYH=10% adjusted grain & straw yield ha-1; GR= gross benefit; TVC=total variable cost; NB= net benefit; D=dominated and MRR=marginal rate of return in percent.

Table.3 Economic analysis for grain and straw yield for interaction of seed rate and row spacing on upland rice at Pawe

RS	SR	GYH	STY	AGY	ASY	TVC	GB	NB	DO	MRR (%)
30	40	3337.5	3634.3	3003.75	3270.87	2010.563	40042.73	38032.17	-	-
30	60	3661.6	4244.5	3295.44	3820.05	2334.316	44214.23	41879.91	-	1188
25	40	3471.7	3929.2	3124.53	3536.28	2428.68	41816.48	39387.8	D	
30	80	3790.3	4316	3411.27	3884.4	2631.691	45682.84	43051.15	-	393.9
25	60	3473.2	3893.5	3125.88	3504.15	2708.882	41793.41	39084.53	D	
20	40	3448.9	3807.2	3104.01	3426.48	2775.602	41436.04	38660.44	D	
30	100	3288.2	4401.2	2959.38	3961.08	2843.907	40353.88	37509.97	D	
25	80	3543.1	3927.7	3188.79	3534.93	2998.319	42585.95	39587.63	D	
20	60	3598.1	4094	3238.29	3684.6	3075.744	43362.88	40287.14	D	
15	40	3237.9	3696.6	2914.11	3326.94	3097.117	39035.58	35938.46	D	
30	120	3501.4	4055.9	3151.26	3650.31	3152.689	42276.61	39123.92	D	
25	100	3398.1	3983.2	3058.29	3584.88	3258.744	41081	37822.26	D	
20	80	3855.7	4436.4	3470.13	3992.76	3390.52	46521.6	43131.08	-	10.53
15	60	3391.8	4092.3	3052.62	3683.07	3397.893	41132.97	37735.08	D	
30	140	3531.8	4296.5	3178.62	3866.85	3436.793	42869.59	39432.8	D	
25	120	3596.3	4314.7	3236.67	3883.23	3565.501	43586.21	40020.71	D	
20	100	3569.9	4299	3212.91	3869.1	3631.937	43283.82	39651.88	D	
15	80	3592.3	3897.8	3233.07	3508.02	3704.961	43084.42	39379.46	D	
30	160	3468.5	4296.3	3121.65	3866.67	3708.248	42185.73	38477.48	D	
25	140	3378.5	4166.5	3040.65	3749.85	3816.098	41070.95	37254.85	D	
20	120	3762.1	4615.5	3385.89	4153.95	3937.884	45707.73	41769.85	D	
15	100	3609.4	4127.7	3248.46	3714.93	3987.269	43521.99	39534.72	D	
25	160	3403.9	4407.4	3063.51	3966.66	4099.527	41610.26	37510.73	D	
20	140	3695.3	4508.5	3325.77	4057.65	4208.866	44868.59	40659.72	D	
15	120	3716.1	4442.7	3344.49	3998.43	4281.674	45020.85	40739.18	D	
20	160	3510.6	4450.8	3159.54	4005.72	4463.931	42810.36	38346.43	D	
15	140	3532.3	4534.1	3179.07	4080.69	4536.861	43136.35	38599.49	D	
15	160	3549.5	4722.5	3194.55	4250.25	4819.183	43529.35	38710.17	D	

GYH=grain yield ha^{-1}; STYH= straw yield; AGYH & ASTYH=10% adjusted grain & straw yield ha-1; GR= gross benefit; TVC=total variable cost; NB= net benefit, DO dominancy and MRR=marginal rate of return in percent.

Table.4 Analysis of variance (ANOVA) for yield and Yield component affected by seed rate and row spacing of upland rice.

Source	DF	PH	TT/0.5 m	PL	FG	UFG	BY	GYH	HI	TKW	STY
LC	3	9432.92126**	41.022375NS	59.4144804**	22799.2454**	49.7105053**	19891344.62**	15053455.96**	1792.642395**	17.0455161**	16558112.71**
Rep	2	31.95853^{NS}	85.039381NS	1.7330795NS	615.16608NS	2.7639967NS	633763.63NS	225125.62NS	8.702303NS	0.6705202NS	164146.85NS
RS	3	25.3534NS	1732.643406**	0.8433022NS	544.91372NS	1.8730886NS	2264986.79*	488773.85*	3.857924NS	1.8247158NS	669954.01*
SR	6	105.6129**	1024.77544**	7.0242377NS	3020.29768**	10.8079716*	3494641.03**	374160.54^{NS}	58.67778**	1.3572635NS	2343440.56**
LC*Rep	6	63.15239*	158.292652*	5.8101092NS	685.4691NS	2.469275NS	9355062.24**	818873.67**	111.426072**	2.534776NS	5587124.89**
LC*RS	9	27.19556NS	114.179372*	3.4568806NS	402.32453NS	3.6429273NS	1322866.34NS	323771.03NS	8.605335NS	0.3545253NS	412971.77NS
LC*SR	18	16.21704NS	53.09766NS	2.7214512NS	336.1448NS	4.009656NS	1289460.84NS	185381.19NS	12.860284*	2.1970998NS	729738.69*
Rep*RS	6	21.91979NS	38.257747NS	1.4511627NS	129.69072NS	1.7575522NS	455515.38NS	70849.73NS	8.331724NS	1.23979NS	272708.94NS
Rep*SR	12	12.12802NS	37.111572NS	1.5625231NS	488.22664NS	1.5268344NS	319126.84NS	132306.36NS	7.946345NS	0.871997NS	123701.16NS
RS*SR	18	27.1284NS	68.556389NS	1.8163249NS	292.96113NS	2.9826488NS	697147.58NS	108531.44NS	10.420679*	1.3816104NS	380332.27NS
LC*Rep*RS	18	11.36355NS	41.95708NS	1.5039703NS	288.42414NS	2.5457149NS	864644.9NS	211432.6NS	5.103182NS	0.836975NS	275874.66NS
LC*Rep*SR	36	20.40035NS	40.875742NS	1.1372127NS	308.49499NS	2.3252037NS	1095625.83NS	167527.73NS	6.663324NS	1.4248977NS	497169.28*
LC*RS*SR	54	18.23806NS	42.715373NS	1.8242842NS	335.81146NS	2.6495445NS	736862.48NS	122865.07NS	6.240632NS	1.1238401NS	338786.99NS
Rep*RS*SR	36	26.35033NS	41.007607NS	1.7357331NS	200.62783NS	3.0207961NS	484799.48NS	114105.06NS	5.850373NS	0.7337361NS	209884.66NS
LC*Rep*RS*SR	100	23.0195NS	51.411329NS	2.3394984NS	383.50406NS	2.3218987NS	707358.38NS	200680.1NS	7.743973NS	1.2266214NS	251244.07NS
Error	8	13.458	32.28516	2.335	240.258	1.8925	456816.1	114154.1	2.889	0.9763062	153653.8
CV(%)		5.215	13.82098	8.5868	17.375	34.632	8.75	9.748	3.7131	3.76312	9.3337

Straw Yield per hector and Harvesting Index

The result indicated that straw yield was significantly ($p \leq 0.05$) affected by main effect of row spacing; and straw yield and harvesting index was highly significant ($p \leq 0.01$) affected by main effect of seeding rate per ha^{-1}.

The highest straw yield (4315.9 kg ha^{-1}) was recorded by 20 cm row spacing, but at par with 15 cm row spacing. The highest straw yield (4469.21 kg ha^{-1}) was gained by seed rate 160 kg ha^{-1} but at par with 140 and 120 kg per ha^{-1}. This result has harmony with (sultana *et al.*, 2012) which revealed that as seed rate increased straw yield was also increased due to higher number of total fillers. The straw yield was highly significantly ($P<0.01$) affected by the main effect of seed rate in which the highest straw yield was observed by applying seed rate of 100 kg and 160 kg ha^{-1} (Zelalem *et al.*, 2020).

The highest number of HI (47.29 %) was recorded on 40 kg ha^{-1}, but at par with 80 kg ha^{-1}and the lowest was 160 kg ha^{-1}. The ability of a crop to convert the dry matter into economic yield is indicated by its harvest index. The higher the harvest index value, the greater the physiological potential of the crop for converting the dry matter to grain yield (Zelalem *et al.*, 2020). Sink formation and ripening are the two physiological processes that explain the improvement in HI. So this indicated that when seed rate increased, HI decreased which is more biological growth than grain production.

Economic (Partial budget) analyses

The partial Budget analysis showed that the highest net benefit (NB 43051.15 birr ha^{-1}) with acceptable MMR (555.65%) was found applying 80 kg ha^{-1} seeding rate per ha. Depend on row spacing the highest NB (41773.9 birr) was from 20 cm, but it was not far from NB (41058.4 birr) of 30 cm row spacing and easily applicable for oxen plough farmers. Before this Zewdineh Melkie, (2020) recommendation, 30 cm row spacing with 96 kg N ha^{-1} was recommended in Pawe areas on up-land rice varieties.

Recommendation

The experiment indicated that main effect of row spacing was highly significant on total tiller per 0.5m row length, and significant difference on biomass yield, grain yield and straw yield. Main effect of seeding rate was highly significant on plant height, TT/0.5 m row length, fertile grain, Biomass yield harvesting index and straw yield. Among the treatment, the highest BY (8.01 ton ha^{-1}) was recorded on 120 kg seeding rate and maximum grain yield (3695.35 kg ha^{-1}) was recorded from 80 kg ha^{-1}). Partial budget analysis also showed that highest NB (43051.15 birr ha^{-1}) with acceptable MRR (393.9%) was found from row spacing 30 cm with 80 kg ha-1. Depend on the above result, recommended seeding rate (80 kg) and 30 cm row spacing is economical feasible and applicable on up land rice varieties for farmers in Pawe areas and similar agro ecologies.

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