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Performance Evaluation of Red Pepper Varieties and Types of Seed Bed for The Management of Root Rot (Phytophtora Capsici) Disease at Central Gondar, Northwest, Ethiopia.

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Abstract

Root rot caused by Phytophtora capsici is one of the most important root diseases of pepper. The experiment was conducted at Denbiya and Takusa district with aimed to evaluate effective red pepper varieties and types of seed bed against root rot disease. Five red pepper varieties namely Melka Dera, Melka Oli, Melka Zala, Marco Fana, local; and two seed bed types namely flat and raised bed were used as treatments. Treatments were arranged in a factorial combination in RCBD with three replication. Result showed that the minimum incidence and severity of 28.13 % and 19.8%, respectively was recorded from Melka Oli variety transplanted in a raised bed while the maximum incidence and a severity of 51.03% and 42.8%, respectively were recorded from local red pepper in flat seed bed. The maximum grain yield of 28.81 q/ha and insignificance yield losses were recorded from Melka Oli in raised beds while the minimum grain yield and maximum yield losses 11.12q/ha and 61.44%, respectively were recorded from local red pepper in flat seed bed. Therefore, results suggested that the use of Melka Oli variety transplanted at raised seed bed is promising for significant reduction in root rot incidence and a corresponding increase in yield of red pepper.

Key words: Root Rot, Phytophtora Capsici, Disease Incidence, Severity, AUDPC, Relative Yield Loss.

Introduction

Red pepper(Capsicum frutescence L.) is one of the most important vegetable crop in the world belonging to the family Solanaceae and grown as spice crop in different parts of the world [1]. It covers 67.98% of all the area under vegetables in Ethiopia [2]. It is the main part in the daily diet of most Ethiopian societies. The average daily consumption of red pepper by Ethiopian adult is estimated at 15 g, which is higher than tomatoes and most other vegetables. Red pepper is a popular vegetable and plays an important role in the national economy of the country. It serves as row material for the processing industries, important cash crop to farmers, and a source of employment to urban and rural populations [3]. However, red pepper production for dry pod has been low with a national average yields of 1.8 t/ha and declining with time [2, 4].

The main constraints that contributed for lower productivity in Ethiopia mainly due to a number of biotic and abiotic factors. Among biotic factors, root rot, fusarium wilt, bacterial leaf spot, bacterial soft rot, powdery mildew, anthracnose and cercospora leaf spot [5] and abiotic factors the use of low yielding varieties, drought, heat, soil salinity and low soil fertility, traditional and backward production system, lack of proper and adequate inputs (fertilizers, improved seeds, pesticides, etc.,), lack of research outputs and lack of extension services on production techniques, are the most important limiting factors [6].

Root rot disease caused by Phytophthora capsici, has become a serious threat to pepper production and causes up to 100% yield losses in commercial peeper fields [7, 8]. The fungus is obligate necrotrophy and the most destructive soil inhabiting pathogens reported so far on Capsicum spp [9, 10]. It is a serious threat to agriculture worldwide, continuously reducing yields and jeopardizing crop survival. Depending on the causal agent, host susceptibility, and the environmental conditions, entire fields can be lost to this disease [11]. An alternative strategy for the management of root rot, which is both sustainable and environmentally compatible, is including planting resistant pepper varieties, careful management of irrigation water, growing pepper on raised beds and crop rotation. The identification of red pepper varieties resistant to Phytophthora capsici will contribute to the development of a plant health management program that favors the sustainability of this crop [12, 13].

In spite of the occurrence of root rot caused by Phytophthora capsicii in commonly growing varieties in most parts of country every year, limited research efforts have been made to find out source of resistance and develop suitable methods for its management in Ethiopia [14, 15]. In Ethiopia research on vegetables in general and pepper in particular has been aimed primarily at identification of new varieties for high yield and disease resistance as well as cultural practices for increasing yield. Therefore, the present studies was initiated with the objectives of evaluate the best performance of red pepper varieties and types of seed bed for resistance against root rot disease development; growth, yield and yield component of red pepper.

Materials and Methods

Description of Study Area

The field experiment was conducted during 2018 main cropping season on Phytophtora capsici sick plot at Takusa and Denbiya district, central Gondar zone, Northwest Ethiopia, which is located $10^0$42' N latitude and $37^0$4' E longitude. The experiment was conducted during rainy season on the field previously cropped to pepper and is naturally infested by root rot. According to the meteorological data of the site the mean annual rainfall are ranged from 980 up to 1200mm. It is agro-ecologically characterized as warm sub-moist mid land and lies an altitude less than 2200 meters above sea level. The mean annual maximum and minimum temperature are 28.5°C and 16.5°C respectively[16]. Major soil type of the district is clay and clay loam. Mixed farming system is dominantly practiced in the district. Major crops grown in the district are; maize, wheat and spice (white and black cumin)[17].

Treatment and Experimental Design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replication. A total of 10 factorial treatment combinations, four relatively root rot resistance improved red pepper varieties were collected from Melkasa agricultural research center namely, Marko Fana, Melka Zala, Melka Dera, Melka Oli (both improved) and one susceptible local check which was purchased from the local farmer; and two seed beds types, i.e., raised and flat (level) were used as treatment. The gross plot size were 8.4m^2 (3mx2.8m) and the path between plots and blocks were 0.5m and 1m, respectively. The seedlings were transplanted 20 to 25 cm height or 54 days after sowing at spacing of 30 cm between plant and 70 cm between rows. Plots were prepared and fertilized with 150/100 kg/ha N/P locally recommended for pepper pod production[18]. Half of the fertilizer rate of nitrogen was applied at transplanting, while the remaining half, splited into three, was applied during flowering stage at two weeks interval [18]. But the P_2O_5 was applied at planting time only, incorporated in to the soil along the planting row. The source of N and P_2O_5 were urea and di-ammonium phosphate, respectively. Other pertinent agronomic practices applicable to red pepper were also followed in the field based on the recommendation.

Data Collection

The data were collected on three middle rows, leaving border rows in order to avoid border effects. Data on different plant growth characters, pathological data, yield and yield components were recorded. In the field experiment observations of naturally occurring root rot development were inspected at 10-days interval (by counting the healthy) 7 times based on percent of wilt incidence in each plot. Initial recording data for disease incidence was done when wilting symptom were visible on the three to five basal leaves of the plants. Numbers of plants infected in three middle rows were recorded and their means were converted into percentage as the total plant observation.

Disease incidence (DI) on each experimental unit was calculated by using the following way:

$$DI\ (\%) = \frac{\text{Number of plants that shows wilt symptoms}}{\text{Number of both disease infected and healthy plants}} \times 100 \text{------------------------------}(1)$$

Disease severity was recorded on ten randomly tagged plants per plot. It was assessed as the percentage of the total leaf surface covered with gray leaf spot lesions on each expanded leaflet separately at regular intervals using 1-7 standard disease severity scoring scale recommended by Sanogo [19] and amended for the purposes of this study: Where 1 no lesions; 2 necrosis without encircling the stem, usually not visible; 3 necrosis encircling the stem; 4 stem necrosis with <50% defoliation 5 stem necrosis with >50% defoliation, 6 wilting plant and 7 dead plant.

The severity grades were converted into percentage severity index (PSI) for the analysis [20]

$$PSI = \frac{\text{Sum of numerical ratings}}{\text{No: of plants scored} \times \text{maximum score on scale}} \times 100 \ldots\ldots\ldots\ldots (2)$$

Area under progress curve (AUDPC) was calculated for each treatment from the assessment of disease incidence using the formula:-

$$AUDPC = \sum 0.5(X_{i+1} + xi)\ (t_{i+1} - ti) \ldots\ldots\ldots\ldots (3)$$

Where, xi is the cumulative disease severity expressed as a proportion at the itch observation, ti is the time (days after sowing) at the ith observation and n is total number of observations. AUDPC values were expressed in %-days [21]. AUDPC values were used in analysis of variance to compare amount of disease among plots with different treatments.

Relative yield losses were calculated separately for each of the treatments with different levels of disease using the formula of [22] $\%\ RYL = \frac{Y1-Y2}{Y2} \times 100$---(4)

Where, RYL relative yield loss (reduction of the yield and yield component), Y1 the yields which was obtained from plots with maximum protection) and Y2 the yields which was obtained from plots with minimum protection). Relative yield loss with different treatments was calculated with reference the best protected experimental plots.

Statistical Data Analysis

Data on disease parameter such as red pepper root rot incidence, severity, AUDPC%-day, relative yield loss; yield and yield components were subjected to analysis of variance (ANOVA) according to the Duncan Multiple Range Test (DMRT) as suggested by Gomez and Gomez [23] using statistical package SAS system, version 9.2. Least significance difference (LSD) values were used separate differences among treatments mean at 5% probability level. The partial budget analysis as described by CIMMYT was done to determine the economic feasibility. The net benefit was calculated as the difference between the gross benefit (Ethiopian Birr ha^{-1}) and the total costs (Ethiopian Birr ha^{-1}) that varied.

Results and Discussion

Root Rot Disease Incidence

Two-way interaction effect of red pepper varieties and types of seed bed were highly significant at $P < 0.01$ on root rot disease incidence percentage (Table 1). Among interaction effects, the maximum root rot incidence of

56.71% at Denbiya district were recorded from local pepper which was transplanted at flat seed bed, whereas the minimum root rot incidence of 32.70% was recorded from Melka Oli variety which was transplanted at raised seed bed (Table 2). Similarly, the maximum root rot incidence of 45.34% at Takusa district was recorded from local pepper transplanted at flat seed bed while the minimum incidence of 27.56% was recorded from Melka Oli variety transplanted at raised seed bed (Table 2). Among the mean value of two districts the maximum root rot incidence of 51.03% and 46.39% were recorded from local pepper transplanted at flat and raised seed bed respectively while the minimum incidence of 30.13% and 32.36% were recorded from Melka Oli and Melka Dera pepper varieties which were transplanted at raised seed bed respectively (Table 2).

Root Rot Disease Severity

The disease reached its peak level 45 days post transplanting (about 2 weeks after first symptom appearance). Results from the analysis of variance showed that disease severity was significantly affected by pepper varieties, seed bed preparation method and their interaction at $p<0.01$ (Table 1). Among Denbiya district the maximum pepper root rot severity of 2.46 (49.2%) and 2.23 (44.6%) were recorded from local pepper and Melka Zala variety which transplant at flat seed bed, respectively whereas the minimum root rot severity 1.02 (20.4%) and 1.34 (26.8%) were recorded from Melka Oli variety which transplanted at raised and flat seed bed, respectively (Table 2). Similarly, on Takusa district the maximum disease severity of 1.82 (36.4%) was recorded from local in flat seed bed while the minimum of 0.97(19.4%) was recorded from Melka Oli in raising seed bed. However, among mean value of two districts the maximum disease severity of 2.14 (42.8%) was obtained from local pepper in flat bed while the minimum of 0.99 (19.8%) was recorded from a Melka Oli variety transplanted in raising seed bed (Table 2).

Area Under Disease Progress Curve (AUDPC%-Days)

Results from the analysis of variance indicated that AUDPC%-day significantly affected by pepper varieties, seed bed preparation method and their interaction effect at $p<0.01$ (Table 1). Among Denbiya district the maximum AUDPC 287.45%-days value was calculated from local pepper transplanted to flat seed bed, followed by Melka Dera with a flat seed bed which result of 273.78%-day, whereas the minimum AUDPC 234.56%-days and 243.45%-day value were calculated from Melka Oli and Marco Fana varieties which were transplanted at raised seed bed respectively (Table 2). Similarly, at Takusa district the maximum AUDPC 281.02%-days value was calculated from local pepper which was transplanted on flat seed bed while the minimum AUDPC 176.25%-days value was obtained from Melka Oli variety which is transplanted at raised seed bed (Table 2). On the other hand, based on mean value of two districts the maximum AUDPC 284.24%-day value was obtained from local pepper which is transplanted at flat seed bed, whereas the minimum AUDPC 205.41%-day was recorded from Melka Oli variety with raised seed bed (Table 2). Mekonen and Chala [2] who stated that resistance hot pepper varieties had lower AUDPC value as compared to local pepper. These mean that Melka Oli variety which is transplanted raised seed bed has more resistance against root rot disease at both Denbiya and Takusa District as compared to other tested treatment (Table 2).

Table 1 : Significances of mean square values for different traits as affected by red pepper varieties and types of seedbed at Denbiya and Takusa districts during 2018 cropping season.

SV	DF	DI (%)	Severity	AUDPC	SCH	TNFPP	MNFPP	UNFPP	Yield
Replication	(r-1) = 3	1.88ns	0.02ns	1.05ns	7.35*	40.66ns	25.98ns	2.72ns	0.69ns
Treatment	(AB-1) = 9	3.58*	0.67*	12.76*	45.03*	125.75*	128.43*	80.61*	67.45*
Varieties (A)	(A-1) = 4	6.78**	0.76**	15.45**	11.24*	40.91*	90.39*	1.67*	166.46*

Seed bed (B)	(B-1) = 1	9.56**	0.87**	10.75**	8.03*	22.57*	50.96*	0.88*	106.14*
AXB	(A-1)(B-1) = 4	12.67**	0.97**	4.38**	3.45ns	0.49*	0.18*	0.03*	2.93*
Error	(AB-1)(r-1) = 18	3.54	0.05	2.87	2.45	0.31	1.18	0.05	0.39
CV (%)		10.98	12.75	11.56	14.43	7.24	9.59	6.78	7.44

NS non-significant, * significant at $P<0.05$, ** significant at $P<0.01$, SV source of variation, DF degree of freedom, CV coefficient of variation, DI(%) disease incidence percentage, AUDPC area under disease progress curve, SCH stand count at harvest, TNFPP total number of fruit per plant, MNFPP marketable number of fruit per plant, UNFPP unmarketable number of fruit per plant,

Table 2: Two way interaction effects of red pepper varieties and types of seed bed on disease incidence, severity and AUDPC%-day at Denbiya and Takusa during 2018 cropping season.

		DI (%)			DS (1-5)			AUDPC%-day		
Varieties	TSB	Denbiya	Takusa	Mean of DI	Denbiya	Takusa	Mean of DS	Denbiya	Takusa	Mean of AUDPC
Melka Zala	Raised	43.50^{a}	37.04^{c}	40.27^{c}	2.03^{d}	1.52^{d}	1.78^{f}	249.56^{d}	236.66^{d}	243.11^{cd}
	Flat	49.33^{bf}	43.43^{ef}	46.38^{d}	2.23^{e}	1.68^{e}	1.96^{g}	263.67^{bc}	251.35^{bc}	257.51^{b}
Melka Dera	Raised	31.28^{c}	31.45^{b}	32.36^{b}	1.69^{c}	1.18^{b}	1.44^{cd}	261.08^{c}	227.95^{e}	244.52^{c}
	Flat	40.05^{de}	36.67^{c}	38.36^{c}	1.78^{c}	1.35^{c}	1.57^{de}	273.78^{b}	244.62^{c}	259.20^{b}
Marco Fana	Raised	34.11^{cde}	32.87^{b}	34.49^{b}	1.43^{b}	1.28^{bc}	1.36^{bc}	243.45^{de}	219.34^{f}	231.39^{e}
	Flat	45.64^{b}	38.02^{cd}	41.83^{c}	1.75^{c}	1.56^{d}	1.66^{ef}	251.09^{cd}	228.38^{e}	239.74^{cde}
Melka Oli	Raised	30.70^{c}	25.56^{a}	28.13^{a}	1.02^{a}	0.97^{a}	0.99^{a}	234.56^{e}	176.25^{g}	205.41^{f}
	Flat)	38.31^{e}	30.84^{b}	34.33^{b}	1.34^{b}	1.02^{a}	1.28^{b}	245.87^{d}	223.16^{ef}	234.52^{de}
Local	Raised	52.11^{f}	40.67^{de}	46.39^{d}	2.22^{e}	1.69^{e}	1.96^{g}	271.76^{b}	257.73^{b}	264.75^{b}

	Flat	56.71^{g}	45.34^{f}	51.03^{e}	2.46^{f}	1.82^{f}	2.14^{h}	287.45^{a}	281.02^{a}	284.24^{a}
LSD (0.01)		4.51	3.02	3.60	0.22	0.11	0.16	10.51	7.53	9.02
CV (%)		10.34	8.98		8.66	6.75		6.24	7.56	

LSD least significance difference, CV coefficient of variation, TSB types of seed bed, DI(%) disease incidence percentage, DS disease severity, AUDPC area under disease progress curve; means in column followed by the same letter are not show significance difference at $p<0.01$.

Stand Count at Harvest

Significant difference at $P<0.05$ were observed among red pepper varieties and types of seed bed on stand count at harvest (Table 1). According to mean value of two districts the maximum number of plant at harvest (21.17 and 20.67) was obtained from Melka Oli and Melka Zala variety which is transplanted at raised seed bed while the minimum number of plant at harvest (14.99 and 16.23) was obtained from local and Melka Zala which was transplanted with flat seed bed (Table 3). The result indicates that the incidence of the disease have directly relation with number of plant at harvest. The present study suggested that the number of plant at harvest in Takusa was higher than Denbiya district (Table 3).

Total Number of Fruits Per Plant

Total number of fruits per plant was showed significant difference among treatments at $P<0.05$ (Table1). The observed significant differences among treatments agronomic traits reveal the presence of genetic variability of the tested pepper varieties. Based the mean value of two study area the maximum total number of fruits per plant (43.77) was given by local pepper, which was transplanted at raised seed bed, followed by local with flat seed bed and Melka Oli variety transplanted with raised seed bed (40.69 and 33.09), respectively (Table 3). On the other hand the minimum number of fruit per plant (23.60 and 25.91) were recorded from Melka Zala variety transplanted with flat seed bed and Marco Fana variety with flat seed bed (Table 3).

Table 3: Main effects of red pepper varieties and types of seed bed on stand count at harvest and total number of fruit per plant at Denbiya and Takusa district during 2018 cropping season.

Varieties	TSB	Stand count at harvest		Mean of SCH	TNFPP		Mean of TNFPP
		Denbiya	Takusa		Denbiya	Takusa	
Melka Zala	Raised	14.87^{cd}	20.67^{ab}	17.77^{b}	24.34^{f}	27.73^{f}	26.04^{e}
	Flat	13.33^{ef}	19.13^{de}	16.23^{d}	22.34^{g}	24.85^{g}	23.60^{f}
Melka Dera	Raised	15.66^{bc}	20.03^{bc}	17.85^{b}	28.46^{cd}	30.34^{de}	29.40^{d}
	Flat	14.12^{de}	18.79^{e}	16.46^{d}	25.46^{f}	28.66^{ef}	27.06^{e}
Marco Fana	Raised	16.03^{ab}	20.19^{bc}	18.11^{b}	26.05^{ef}	29.45^{ef}	27.75^{de}
	Flat	14.76^{cd}	18.65^{e}	16.71^{cd}	24.23^{fg}	27.59^{f}	25.91^{e}
Melka Oli	Raised	17.04^{a}	21.17^{a}	19.11^{a}	30.35^{c}	35.72^{c}	33.09^{c}

	Flat	15.49^{bc}	19.63^{cd}	17.56^{bc}	27.56^{de}	31.86^{d}	29.71^{d}
Local	Raised	14.61^{cd}	18.43^{e}	16.52^{d}	41.89^{a}	45.65^{a}	43.77^{a}
	Flat	13.06^{f}	16.93^{f}	14.99^{e}	39.45^{b}	41.92^{b}	40.69^{b}
LSD (0.05)		1.06	0.82	0.95	1.99	2.05	2.02
CV		6.75	4.67		8.67	7.24	

LSD least significance difference, CV coefficient of variation in percent, TSB types of seed bed, SCH stand count at harvest, TNFPP total number of fruit per plant; means in column followed by the same letter are not show significance difference at p<0.05.

Marketable Number of Fruits Per Plant

Analysis of variance showed that marketable number of fruits per plant significantly affected by pepper varieties, seed bed preparation method and their interaction effect at P<0.05 (Table 1). Based on the mean value of two district the highest number of marketable fruit per plant of 18.03 was recorded from Melka Oli variety transplanted with raised seed bed, followed by Melka Dera with raised seed bed and Melka Oli with flat seed bed which result 14.69 and 13.65, respectively whereas the lowest marketable fruit per plant (3.91) was recorded from local pepper with flat seed bed followed by local with raised bed and Melka Zala variety with flat seed bed which result of 7.22 and 8.12, respectively (Table 4). Delelegne et al. [24] reported that the influence of genetic variability and heritability are necessary in systematic improvement of red pepper varieties for fruit yield and related traits. The recorded variations of varieties in marketable yield could be due to their differences in genetic make-up and/or agro ecological adaptations compared to the locations in which they had evaluated which is in line with the findings of Alayachew et al, [25] who reported that the magnitude of genetic variability and heritability are necessary in systematic improvement of hot pepper for fruit yield and related traits.

Unmarketable Number of Fruit Per Plant

Analysis of variance revealed that marketable number of fruits per plant significantly affected by pepper varieties, types of seed bed and their interaction effect at P<0.05 (Table 1). Among the mean value of two study area the maximum unmarketable number of fruit per plant (6.71) was given by local pepper with flat seed bed followed by local with raised seed bed and Marco Fana variety with flat seed bed (6.12 and 5.86) respectively while the minimum unmarketable number of fruit per plant (4.08 and 4.31) were recorded from Melka Oli and Melka Dera variety which was transplanted with raised seed bed respectively (Table 4). The result indicates that unmarketable number of fruit per plant in Denbiya district was higher than Takusa.

Table 4: Two-way interaction effect of red pepper varieties and types of seed bed on MUFPP and UNFPP at Denbiya and Takusa district during 2018 cropping season.

Variety	TSB	MNFPP		Mean of MNFPP	UNFPP		Mean of UNFPP
		Denbiya	Takusa		Denbiya	Takusa	
Melka Zala	Raised	10.14^{d}	11.64^{e}	10.89^{d}	6.02^{cd}	4.02^{b}	5.02^{d}
	Flat	8.16^{e}	8.04^{f}	8.12^{e}	6.67^{bc}	4.21^{b}	5.44^{c}
Melka Dera	Raised	13.57^{b}	15.82^{b}	14.69^{b}	5.17^{e}	3.45^{a}	4.31^{e}

	Flat	10.36^{d}	13.46^{d}	11.91^{d}	5.01^{e}	5.02^{cd}	5.02^{d}
Marco Fana	Raised	11.45^{c}	14.02^{cd}	12.74^{c}	5.41^{de}	4.99^{c}	5.21^{cd}
	Flat	9.75^{d}	11.01^{e}	10.38^{d}	6.48^{bc}	5.23^{de}	5.86^{b}
Melka Oli	Raised	16.45^{a}	19.62^{a}	18.03^{a}	3.91^{f}	4.25^{b}	4.08^{e}
	Flat	12.05^{c}	15.25^{bc}	13.65^{bc}	5.42^{de}	4.78^{c}	5.12^{cd}
Local	Raised	6.45^{f}	7.99^{f}	7.22^{e}	7.18^{b}	5.05^{cd}	6.12^{b}
	Flat	4.03^{g}	3.91^{g}	3.97^{f}	8.07^{a}	5.34^{e}	6.71^{a}
LSD (0.05)		1.06	1.73	1.55	0.74	0.28	0.39
CV		11.78	9.59		7.48	6.783	

LSD least significance difference, CV coefficient of variation in percent, TSB types of seed bed, MNFPP marketable number of fruit per plant, UNFPP unmarketable number of fruit per plant; means in column followed by the same letter are not show significance difference at p<0.05.

Yield of Red Pepper

The analysis of variance for yield were showed significant difference among pepper varieties, types of seed bed and their interaction effect at P<0.05 (Table 1). The variation in mean yield between the tested varieties was attributed to their genetic potential for yield and disease resistance. Accordingly, based on the mean value of two districts the maximum grain yield of 28.81q/ha were obtained from Melka Oli variety which transplanted on raised seed bed, followed by Melka Dera and Marco Fana pepper varieties which were transplanted at raised seed bed resulted in 24.97q/ha and 24.70q/ha, respectively (Table 5). On the contrary, the minimum yield of 11.12q/ha was obtained from local pepper transplanted with flat seed bed, followed by local pepper with raised seed bed and Melka Zala variety which was transplanted at flat seed bed which result of 16.04 q/ha and 16.9q/ha, respectively (Table 5). The result indicates that yield of red pepper is maximum in Takusa district than Denbiya. This result is further consolidated by the findings of Kahsay [14] who reported positive impact of vegetative growth up on yield and yield components of red pepper.

Yield Losses of Red Pepper

According to mean value of two district the analysis of variance revealed that relative yield loss of red pepper significantly affected by pepper varieties, types of seed bed and their interaction at P<0.05(Table 5). Among red pepper varieties the maximum yield losses of 61.44% was calculated in local pepper which was transplanted with flat seed bed, followed by local pepper with raised seed bed and Melka Zala variety transplanted on flat seed bed which resulted in yield losses of 43.33% and 41.44% respectively (Table 6). On the contrary the minimum grain yield losses was obtained from Melka Oli variety transplanted on raised seed bed which results of negligible losses, followed by Marco Fana and Melka Dera varieties which transplanted on raised seed bed which results of 12.23% and 13.45%, respectively (Table 6).

Table 5: Two-way interaction effect of red pepper varieties and types of seed bed on yield and their corresponding loss due to root rot disease at Denbiya and Takusa district during 2018 cropping season.

	Yield (q/ha)	RYL (%)

Variety	TSB	Denbiya	Takusa	Mean of yield (q/ha)	Denbiya	Takusa	Mean of RYL (%)
Melka Zala	Raised	19.34^{d}	24.65^{b}	22.10^{bc}	28.51	19.34	23.93
	Flat	15.34^{e}	18.46^{de}	16.90^{de}	43.29	39.59	41.44
Melka Dera	Raised	22.89^{c}	27.04^{ab}	24.97^{b}	15.38	11.52	13.45
	Flat	17.45^{d}	20.83^{cd}	19.24^{cd}	35.49	31.84	33.67
Marco Fana	Raised	25.03^{a}	25.37^{b}	24.70^{b}	7.47	16.98	12.23
	Flat	19.34^{d}	20.28^{de}	19.71^{cd}	28.51	33.64	31.08
Melka Oli	Raised	27.05^{a}	30.56^{a}	28.81^{a}	0.00	0.00	0.00
	Flat	22.54^{c}	24.28^{bc}	23.41^{b}	16.67	20.55	18.61
Local	Raised	15.04^{e}	17.03^{e}	16.04^{e}	44.39	42.27	43.33
	Flat	10.23^{f}	12.01^{f}	11.12^{f}	62.18	60.7	61.44
LSD (0.05)		2.05	3.75	2.91			
CV (%)		10.23	7.43				

LSD least significance difference, CV coefficient of variation in percent, TSB types of seed bed, RYL relative yield loss, means in a column followed by the same letter are not show significance difference at $p<0.05$.

Economic Analysis

The partial budget analysis revealed that the highest net benefit of Birr 119,150 birr/ha was recorded in the treatment that received Melka Oli pepper variety transplanted with raised seed bed while the lowest net benefit (22.530.00 birr/ha) was obtained from the treatment received local pepper with flat seedbed (Table 6). On the contrary, the highest marginal rate of return (MRR) of 3,460% was obtained from Melka Oli variety transplanted with raised seed bed while the lowest MRR 400% was obtained from Melka Dera with raised seed bed (Table 6). This implies that for every Birr 1.00 that a farmer invests for red pepper cultivation, he expected Birr 1.00 plus additional Birr 34.6 and 4, respectively. Recommended treatment combinations should result maximum possible return with the possible minimum cost. However, considering the net benefit, Melka Oli variety transplanted with raised seed bed which results maximum additional profit than others. Thus, Melka Oli variety transplanted with raised seed bed could be recommended as a first alternative.

Table 6: Economic analysis for red pepper varieties and types of seed bed at Denbiya and Takusa district during 2018 cropping season.

Treatments		Average	AY 10%	GB	TVC	MC	NB	MNB	MRR
Varieties	TSB	yield (q /ha)	(q/ ha)	(Birr /ha)	(Birr/ ha)	(Birr/ha)	(Birr /ha)	(birr/ha)	(%)
Local	Flat	11.12	10.01	30,030	7,500	-----	22,530	---	

	Raised	16.04	14.44	43,320	10,500	2,500	32,820	10,290	411.6
Melka Zala	Flat	16.90	15.21	76,050	8,000	2,000	68,050	35,230	1,761.5
	Raised	22.10	19.89	99,450	10,500	2,500	88,950	20,900	836
Marco Fana	Flat	19.24	17.32	86,600	8,000		78,600**D**		
	Raised	24.70	22.23	111,650	11,000	500	100,650	11,700	2,340
Melka Dera	Flat	19.71	17.74	88,700	8,000		80,700**D**		
	Raised	24.97	22.47	113,150	11,300	300	101,850	1,200	400
Melka Oli	Flat	23.41	21.07	105,350	8,000		97,350**D**		
	Raised	28.81	25.93	130,950	11,800	500	119,150	17,300	3,460

TSB types of seed bed, AY adjusted yield, GB growth benefit, TVC total variable cost, MC marginal cost, NB net benefit, MNB marginal net benefit, MRR marginal rate of return and D dominance analysis

Conclusion and Recommendation

The present study suggested that the adoption of resistance variety Melka Oli which was transplanted at raising seed bed results in reduce root rot disease progress with a corresponding increase yield of pepper. Further, undoubtedly the root rot appears to be an important disease that calls for better attention in the study area in terms of integrated management through use of the resistant varieties and types of seed bed. The variety Melka Oli transplanted at raised seed bed appears to have better resistance against the root rot disease. However, for maximum net benefit, we recommend Melka Oli variety with raised bed; Farmers may have the opportunity to decrease yield loss due to root rot disease and to increase pepper yield and ultimately improve their livelihoods through adopting the appropriate management practices. Therefore, its genetic resistance needs to be investigated further by repeating the experiment for one more cropping season and location.

Authors' Contributions

YM initiated the research, wrote the research proposal, conducted the research, did data entry and analysis and wrote the manuscript. AB was involved in analysis, methodology, writing, reviewing and editing of the research proposal and manuscript. All authors read and approved the final manuscript.

Availability of Data and Materials

The authors want to declare that they can submit the data used to support the findings of this study are available from the corresponding author and they can submit the data at whatever time based on your request.

Conflict of Interest

The authors declare that they have no competing interests.

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