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Verifying Wheat-Chickpea Varieties for Double Cropping on the Vertiosols of Central Highland of Ethiopia

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Abstract: Climate change, land scarcity, and anthropogenic factors are the major challenges to agricultural productivity and cause food insecurity to feed the ever-increasing human population. Vertiosols in the central highlands of Ethiopia have the potential to produce a second crop using residual moisture after harvesting the main crop within the same cropping calendar. Farmers are practising double cropping using local varieties because there are neither verified research outputs nor awareness and promotion that support the practise of double cropping in the area. Field experiments were conducted during the 2021 and 2022 cropping seasons at Ejersa Lafo and Dandi districts in the West Shewa zone to evaluate the economic and agronomical feasibility of wheat-chickpea in double cropping combinations. The treatments consisted of four bread wheat varieties (Wane, Dursa, Abay, and Kakaba) and three chickpea varieties (Teketay, Dalot, and Natoli). The experiment was laid out in a randomized complete block design with three replications. The combined result showed that Dursa and Kakaba wheat varieties required the smallest number of days to mature (118 days), whereas Abay and Wane required 125 and 132 days to reach maturity, respectively. Kakaba and Abay varieties produced the highest thousand seed weight and grain yield, whereas Dursa varieties produced a statistically ($P< 0.05$) lower yield and thousand seed weight than the other varieties. The results indicate that the interaction of bread wheat and chickpea varieties had a significant effect on the grain yield of chickpea. Teketay chickpea variety double cropped with Kakaba bread wheat variety gave the highest grain yield (2595.15 kg ha–1). The highest economic benefit (ETB 235193 ha-1) with the highest MRR (275%) resulted from the Teketay chickpea variety, which was double cropped with the Kakaba bread wheat variety. Therefore, Kakaba bread wheat variety and Teketay chickpea variety could be recommended for double cropping on the vertiosol of the west Shewa zone (Dandi and Ejersa Lafo districts) and similar agroecologies.

Keywords: Bread Wheat, Chickpea Variety, Economic Feasibility

1. Introduction

Wheat and chickpeas are staple foods in Ethiopian diet. Although the country is the second largest producer of wheat in Sub-Saharan Africa, it is unable to meet national demand and must rely on imports. Ethiopia's annual production is about 5.8 million tons with mean productivity of 3 tons per hectare (tha^{-1}) [7], which is relatively lower than the attainable yield of the crop, reaching up to 5 t ha^{-1} [19]. Improved cultivars and agronomic practices have significantly increased chickpea production in Ethiopia in recent decades [15]. Increasing crop production by double cropping with essential pulse crops like chickpeas may be a worthwhile alternative for contributing to food and nutrition security while enhancing soil fertility. Chickpea is a high value legume crop in Ethiopia which supports the livelihoods of millions of smallholder farmers [10] and the country is the sixth-largest producer of chickpea globally and the largest in Africa [16]. Chickpea is Ethiopia's third most important export legume after Faba bean and haricot bean, generating a revenue of about US$61 million annually [6]. Since the crop is grown in rotation with cereals (mainly tef and wheat), it does not compete for land [18]. Despite its importance to the country's economy and livelihoods of farmers, the productivity of the crop is low at 2.06 t/ha is far below the potential yield (4 t ha^{-1}) indicating

the need to improve optimum crop management practices [6].

Double cropping has the potential to maximize profit from the same area and season. It is critical to look for the ideal crop combination and compatibility to maximize the system's potential. It was reported that double cropping has many advantages, such as it reduces the risk of field loss due to drought, insect and disease, obtain a better use of vertical space and time in limited farmland [3]. Ethiopia has a huge potential for double cropping practice in its Vertisol dominant areas such as West Shewa zone, South West Shewa zone, North Shewa Zone of Oromia region and West Gojjam, East Gojjam, North Gondar and South Gondar Zones of Amhara region [12, 13]. Mid altitude of west Shewa, Ejersa Lafo and Dandi Distinct have a high potential to produce two crops (bread wheat and chickpea) in one cropping season as a double cropping. scaling out of wheat-chickpea double cropping contributes to food security and rural livelihood improvement through yield and farm income increment. areas have long rainy season (28th May–30th September) and water balance for the area indicates that the moisture availability index is greater than 0.5, and potential evapotranspiration is lower than precipitation during these months [2].

The area can support two crops with great compatibility—wheat under full rain fall and chickpea adapted for limited phenological residual moisture—thanks to the distribution of rainfall and the strong retention of vertisol. The area soil is vertisol, meaning it can hold a lot of water. In order to prevent waterlogging, the vertisol farmers in the Ginchi area typically plant crops on leftover moisture shortly after the main rainy season ends in September. This approach exposes the soil to soil and water erosion and leaves the soil bare in the absence of crop cover. The crops planted on residual moisture sometimes suffer from thermal drought and dry spells [2]. However, some farmers are practicing double cropping using local variety of both crops, because neither confirmed research results nor awareness and promotion that support the use of double cropping in the area exist. Thus, evaluating the viability of double cropping and in the area in terms of technical and economic feasibility is critical and timely. As a result, the experiment's goal will be to assess the economic and technical feasibility of wheat-chickpea varieties in double cropping combinations for improved production systems.

2. Materials and Methods

2.1. Description of the Study Area

The field experiments were conducted under rain-fed conditions during the main cropping season for two consecutive years (2021 and 2022) at Dandi and Ejersa Lafo districts in the West Shewa Zone, central highland of Ethiopia. Dandi experimental site was geographically located at 9.00031°N and 38.00374°E with an average altitude of 2275 m.a.s.l and the Ejersa Lafo experimental site was geographically located at 9. 33412° N and 38. 14697°E with an altitude of 2154 m.a.s.l. The soil texture of the experimental sites is high clay (vertisol) [1]. In the 2021 main cropping season, the mean maximum and minimum temperatures of the two districts during the season of the experiment were 24.4 and 8.70°C, respectively, and the total annual rainfall was 1339.8 mm. In the 2022 main cropping season, the mean maximum and minimum temperatures of the two districts during the season of the experiment were 24.6 and 8.4°C, respectively, and the total annual rainfall was 1332.3 mm.

2.2. Description of Experimental Treatments and Design

The experiment would be conducted in randomized complete block design (RCBD) with three replications. four bread wheat (Wane, Dursa, Abay and Kakaba) three chickpea varieties (Natoli, Tekatey and Dalot) would be used. The plot size of the experiment would be 1.8m x 3m ($5.4m^2$). Each experimental plot had 9 rows for bread wheat and six rows for chickpea. Planting would be done by hand drilling at seed rate of 150 kg ha^{-1} for bread wheat and 130 kg ha^{-1} for chickpea. Fertilizer was applied at the rate of 41/46 kg/ha N and P_2O_5, respectively for bread wheat. All Nitrogen fertilizer was applied once at planting. Urea fertilizer, however, would be applied in split at planting and tillering stages for bread wheat. Crop management practices such as weeding, thinning and plant protection measure were done as per requirement equally for all treatments for both crops.

2.3. Methods of Data Collection

Heading days, Maturity days, Plant height, thousand seed weight of wheat, pod per plant, seed per pod, hundred seed weight of chickpea, and grain yield would be assessed using a representative sample of each treatment from both species.

2.4. Statistical Analysis

The collected data were statistically analyzed using the general linear model (GLM) procedures of the SAS statistical software version 9.4 (SAS Inc., Cary, NC) following the procedure set by Littell et al. [17] to evaluate the effect of appropriate plant population density and NPS fertilizer application. A test of homogeneity of the data was applied and then a combined analysis of variance was performed over the two years using Duncan's multiple range tests (DMRT) were used to compare the treatment means at 5% of probability.

2.5. Economic Analysis

A simple partial budget analysis using the CIMMYT technique was used for economic analysis [8]. The elements having significant effects were included for partial budget analysis. By deducting 10% from the average gain yield, the yield was adjusted. Following that, the gross benefit was calculated by multiplying the modified yield by two years of harvesting months (December-January) average prices of Ethiopian Birr 36 kg-1 for chickpea grain, Ethiopian Birr 38 kg-1 for bread wheat, and Birr 17.5kg-1 for NPS. The net benefit was estimated by deducting the labor cost from the gross yield. Finally, the marginal rate of return (MRR) was calculated. The mean market price of chickpea and bread wheat were obtained by

assessing the market at harvest (2022 cropping season).

3. Results and Discussion

3.1. Effect of Wheat-Chickpea Varieties for Double Cropping on Phenology, Growth, Yield, and Yield Components of Wheat Crop

The combined analysis of the two years and two sites' data showed that in all the agronomic parameters such as maturity days, plant height, spike length, number of tillers per plant, thousand seed weight and grain yield; there were significance ($p<0.05$) difference among treatments. From the four bread wheat varieties tested, varieties Dursa and Kakaba (118 days for maturity) were found to be earlier than the other two testes wheat varieties (table 1). Abay and Wane varieties mature lately and Abay took 125 days to mature, whereas Wane took 132 days to mature. In the double cropping farming system, the maturity date has a considerable impact on the effective exploitation of natural resources, particularly water. As a result, the succeeding chickpea crop planted shortly after the bread wheat harvest appeared to receive adequate moisture for growth. Planting time is crucial in double-cropping systems since maturity times and dates have a significant impact on productivity. Dursa and Kakaba varieties matured 7 and 14 days earlier as compared to other two varieties (Abay and Wane) which were have good compatibility for double cropping. However, the other two bread wheat varieties (Wane and Abay) mature lately, which have weaker compatibility in double cropping concept and affected the productivity of the subsequent chickpea crop (Table 1).

The analysis of variance indicated that plant height was significantly ($P < 0.05$) affected only by the main effect of varieties (Table 1). The result revealed that the lowest plant height (84.82cm) was recorded from Wane variety, while the highest plant height (91.62 cm) was recorded from Abay variety which was statistically at par. with Kakaba and Dursa varieties (91.47cm and 89.72cm respectively) but, numerically Abay variety gave the highest plant height. Dursa variety has high number of primary tiller (5.41) which was statically similar with Abay and wane (Table 1). Similarly, there was significance difference between treatments on spike length and thousand seed weight as well. Varieties Dursa, Abay and Kakaba gave relatively longer spike length (7.13cm, 7.10cm and 6.98cm respectively) than wane. However, Kakaba and Abay has high thousand seed weight (7.39g and 7.23 g respective) than the two bread wheat varieties and thus gave highest grain yield in both site (Table 1).

Significant variations among the varieties were measured for number kernel per spikes. It was shown that varieties Wane and Abay, which produced the highest number of kernels per spikes (40.22 and 41.18 respectively), However, Dursa and Kakaba varieties had the lowest number of kernels per spikes (35.5 and 36.82 respectively). Varieties Wane, Dursa and Kakaba produced statistically similar and higher grain yields while Dursa produced the lowest. The differences in grain yield and biomass yield might have been caused by varietal differences in genetic makeup. This result was agreed with the findings of [9] who reported that early maturity, plant height, number of kernels per spike and number fertile tillers were reported as a function of both genetic and environmental factors [9].

Table 1. *Means for growth and yield parameters of wheat crop as affected by Wheat-Chickpea varieties for Double Cropping during 2021-2022.*

Chickpea Varieties	Parameters							
	MD	**PH (cm)**	**NPT**	**SL (cm)**	**NKPS**	**AGBM (kg ha^{-1})**	**GY (kg ha^{-1})**	**TSW(g)**
Teketay	123.62	89.40ab	4.58b	6.70	38.52	11553.30	4454.30	7.11
Natoli	123.83	90.46a	4.40b	6.82	38.78	11644.80	4410.20	6.98
Dalot	123.45	88.38b	5.9a	6.79	38.39	11521.30	4545.90	7.12
LSD@0.05	0.74ns	1.74	0.69	0.22ns	2.27ns	764.55ns	323.69ns	0.21ns
Wheat verities								
Wane	132.05a	84.82b	4.66a	5.88b	41.18a	11855.00	4624.90a	6.97b
Dursa	118.39c	89.75a	5.41a	7.13a	35.50b	11262.80	3979.50b	6.68c
Abay	125.61b	91.62a	4.77ab	7.10a	40.22a	12009.70	4474.00a	7.39a
Kakaba	118.50c	91.47a	4.28b	6.98a	36.82b	11165.00	4802.20a	7.23a
LSD@0.05	0.86	2.00	0.81	0.25	2.62	882.83	373.77	0.24
CV	1.04	3.36	25.31	5.58	10.21	11.43	12.53	5.03

MD=maturity date, PH (CM)=plant height in centimeter NPT=number of primary tillers, SL=spike length, NPBPP=number of primary branches per plant, AGB=above ground biomass=grain yield=Grain yield, SMC=seed moisture content, SW=thousand seed weight

3.2. Effect of Bread Wheat and Chickpea Varieties on Growth and Yield of Chickpea Crop During Double Cropping

The analysis of variance indicated that plant height was significantly ($P < 0.05$) affected only by the main effect of varieties (Table 2). The result revealed that the highest plant height (50.29cm) was recorded from Teketay variety, while the lowest plant height (43.66cm) was recorded from Natoli variety which was statistically at par. with Dalot. This result was agreed with the findings of [14], who reported that from the three chickpea varieties tested for double cropping Teketay variety gave the tallest plant height as compared to the other two chickpea varieties. It also more supported with the finding of [4], who reported that Teketay variety gave higher plant height than Natoli and Dalot varieties from the four chickpea varieties tested for determining the optimum phosphorus fertilizer application rates of chickpea. The main effect of chickpea and bread wheat variety had a significant ($P < 0.05$) effect on the number of pods per plant, thousands of

seed weight and seed yield per plant. Natoli variety gave higher thousand seed weight (361.20g), while Teketay and Dalot variety gave lower thousand seed weight (320 g and 315.37 g respectively) (table 2).

The combined analysis of the two years data of both sites indicated interaction effect of chickpea and bread wheat varieties had a significant ($P < 0.05$) effect on the biomass and grain yield of chickpea. The mean separation analysis revealed that the highest above ground biomass (7448.10 $kgha^{-1}$) was obtained at interaction of Kakaba bread wheat variety with Teketay chickpea variety double cropping, while the least above ground biomass (2973.90 $kgha^{-1}$) was found at the interaction of Abay bread wheat variety with Dalot chickpea double cropping (Table 3).

The result of this study revealed that the interaction of bread wheat and chickpea varieties was significantly ($P<0.05$) influenced grain yield of chickpea. The highest grain yield (2595.15 kg ha^{-1}) was obtained from the combined Kakaba bread wheat variety with Teketay chickpea variety but, the lowest grain yield was obtained from Abay bread wheat variety with Dalot chickpea variety (2081.50 kg ha^{-1}) of double cropping system (Table 3). This indicate that Kakaba wheat variety matures averagely within 118 days in the main rainy season (June–September); leaving adequate growing period for the following crop (chickpea). Early maturing wheat variety allow the chickpea plant to get sufficient moisture (a more yield determining factor), which might support the produce the maximum grain yield. Similar finding was reported by [11] double cropping of wheat with chickpea provided the highest grain yield of 2.7 t/ha for the wheat variety and 2.6 t/ha for the chickpea variety in just one growing season (June–December). This result was also supported with the findings of [5], who reported that Teketay variety produced significantly highest biological yield (6880.8 kg), while the lowest biological yield (3392.8 kg) was observed in case of local variety and showed its superiority yield over Natoli and Dalot variety.

Table 2. *Means for phenology, growth and yield parameters of Chickpea crop as affected by Wheat-Chickpea varieties for Double Cropping over sites during 2021-2022.*

Chickpea Varieties	Parameters				
	PH (cm)	NPBPP	NPPP	NSPP	TSW(g)
Teketay	50.29[a]	8.31	79.02	1.45	320.00[b]
Natoli	43.66[b]	7.94	68.25	1.38	361.20[a]
Dalot	44.62[b]	8.29	72.56	1.37	315.37[b]
LSD@0.05	2.87	1.33ns	18.73ns	0.18ns	35.04
Wheat verities					
Wane	45.50	8.03	66.17	1.36	351.69
Dursa	46.03	8.30	79.53	1.43	328.05
Abay	46.66	8.72	74.56	1.48	324.47
Kakaba	46.58	7.66	72.86	1.33	324.56
LSD@0.05	3.32ns	1.54ns	21.63ns	0.21ns	40.46ns
CV	7.35	19.29	30.18	15.01	12.46

MD=maturity date, PH (CM)=plant height in centimeter NPT=number of primary tillers, SL=spike length, NPBPP=number of primary branches per plant, AGB=above ground biomass=grain yield=Grain yield, SMC=seed moisture content, SW=thousand seed weight

Table 3. *Interaction effect of Bread wheat varieties and chickpea varieties on biomass and grain yield of chickpea over site during 2021-2022.*

Above ground Biomass (kg ha-1)				Grain yield (kg ha-1)		
Wheat varieties	Chickpea varieties			Chickpea varieties		
	Teketay	Natoli	Dalot	Teketay	Natoli	Dalot
Wane	6628.70b[cd]	6094.40[de]	6637.50[bcd]	2509.67[ab]	2123.50[e]	2312.70[de]
Dursa	7110.70[ab]	6985.00[ab]	6310.50[cde]	2477.60[ab]	2433.80b[c]	2198.77[de]
Abay	6024.90[e]	6831.50[bc]	5973.90[e]	2099.25[e]	2380.30[bc]	2081.50[e]
Kakaba	7448.10[a]	6772.60[bc]	7045.90[ab]	2595.15[a]	2359.80[bc]	2455.00[abc]
LSD at 0.05	554.78			158.82		
CV%	4.92			4.02		

Means followed by different letters in columns are statistically significant at 5% probability l

3.3. Economic Analysis

Economic analysis was done to compare the financial feasibility of each treatment. The result of the partial and marginal analysis (Table 4) showed that the highest net benefits (ETB 235193 ha^{-1}) were obtained from Teketay chickpea variety was double cropped with Kakaba bread wheat variety followed by Dalot chickpea variety was double cropped with Kakaba bread wheat variety (ETB 232154 ha^{-1}). On the other hand, the lowest net benefit (ETB 185746 ha^{-1}) was recorded from Dalot chickpea variety was double cropped with Dursa bread wheat variety (table 4).

The partial budget, marginal analysis, and minimum rate of return together give the information necessary to arrive at a tentative or candidate recommendation. The marginal return rate (MRR) result showed that double cropping of Kakaba chickpea variety with Teketay wheat variety had 275 % MRR. Similar to this finding, [13] reported that adoption of wheat-chickpea double cropping has a positive and significant

impact both on yield and farm income of smallholder farmers.

Table 4. *Economic analysis of Chickpea and bread wheat varieties for double cropping.*

Treatments		Chickpea		Bread wheat		GB (EB ha $^{-1}$)	TVC (EB ha $^{-1}$)	NB (EB ha $^{-1}$)	MRR (%)
Bread wheat variety	Chickpea Variety	GY (Kg ha $^{-1}$)	AGY (Kg ha $^{-1}$)	GY (Kg ha $^{-1}$)	AGY (Kg ha $^{-1}$)				
Wane	Teketay	2509.70	2258.73	4673.53	4206.18	241149.01	22215	218934	
Wane	Natoli	2269.00	2042.10	4673.53	4206.18	233350.33	22215	211135	D
Wane	Dalot	2442.50	2198.25	4673.53	4206.18	238971.73	22215	216757	56
Dursa	Teketay	2477.60	2229.84	3997.67	3597.90	216994.55	22215	194780	D
Dursa	Natoli	2433.80	2190.42	3997.67	3597.90	215575.43	22215	193360	D
Dursa	Dalot	2198.80	1978.92	3997.67	3597.90	207961.43	22215	185746	D
Abay	Teketay	2245.80	2021.22	4549.55	4094.60	228358.53	22215	206144	204
Abay	Natoli	2380.30	2142.27	4549.55	4094.60	232716.33	22215	210501	44
Abay	Dalot	2293.30	2063.97	4549.55	4094.60	229897.53	22215	207683	D
Kakaba	Teketay	2548.80	2293.92	5111.90	4600.71	257408.10	22215	235193	275
Kakaba	Natoli	2359.80	2123.82	5111.90	4600.71	251284.50	22215	229070	D
Kakaba	Dalot	2455.00	2209.50	5111.90	4600.71	254368.98	22215	232154	31

GY= grain yield, AGY= adjusted grain yield (10% down), GB= gross benefit, TVC = total variable cost, NB= net benefit MRR=marginal rate of return and EB=Ethiopian birr.

4. Conclusion and Recommendation

According to this study's findings, the Kakaba variety of bread wheat performed better than the other four types in terms of early maturing and grain production, and the Teketay variety of chickpeas outperformed the other three kinds in terms of yield. Bread wheat varieties' maturity days have a significant impact on the overall grain output. With the largest net benefits (ETB 235193 ha), the Kakaba wheat variety (4802.20 kg ha-1) and Teketay chickpea variety (2595.15 kg ha-1) produced the maximum grain production in the wheat-chickpea double cropping farming system. Therefore, it is advised for places with an agroecology similar to that of Ejersa Lafo and Dandi District, which use a double cropping agricultural method on vertisols, to double crop the Kakaba bread wheat variety with the Teketay chickpea variety.

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Conflicts of Interest

The authors declare no conflicts of interest.

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