Agronomic and Economic Evaluation of Wheat-Chickpea Double Cropping on the Vertisol of Takusa, North Western Ethiopia

Tsedalu Jemberu[1], Asnake Fikre[2], Yimer Abeje[1], Birkie Tebabal[1], Yonas Worku[1] and Tesfaye Jorgi[1]

[1]*Gondar Agricultural Research Center. P.O.Box 1337, Gondar, Ethiopia, E-mail: tsedalu2009@gmail.com*
[2]*International Crops Research Institute for the Semi-Arid Tropics (ICRISAT-Ethiopia) (C/o ILRI), P.O. Box 5689, Addis-Ababa, Ethiopia*

Abstract

Takusa district in north Gondar zone has a high potential for double cropping per one growing season. Farmers in the area, however, do not practice double cropping so far, a reflection of lack of research outputs that addressed its feasibility. The objective of this study was, therefore, formulated around the need to evaluate the technical and economic feasibility of double cropping in the area using wheat-chickpea. Experiments were established at Takusa district during the 2015 main cropping season. The trials were laid down in factorial arrangement of randomized complete block design (RCBD) with three replications. Three bread wheat varieties (Senkegna, Tay and Dinknesh) and two chickpea varieties (Habru and Natoli) were used. The combined data showed that, wheat variety Dinknesh took the shortest days to mature (81 days) compared to Senkegna and Tay (97 days each) varieties. The highest thousand seed weight and grain yield was observed on variety Denknesh and has significance difference at P<0.05 with the other two varieties. Sole planting of Natoli (2926 kg/ha) and Habru (2103kg/ha) chickpea varieties gave relatively higher yield when compared with their respective double cropping combination. The Marginal rate of return (MRR) result showed that double cropping Natoli chickpea variety with Denekinesh wheat variety had 104% MRR. The land equivalent ration demonstrated double cropping rewards to a maximum of 1.99, implying the yield and benefit maximization per unit area per season. The highest grain yield in the double cropping system was obtained with Dinknesh wheat variety (2709kg/ha) double cropped with Natoli chickpea variety (2562 Kg/ha) and this combination could be recommended for similar agroecologies.

Keywords: Chickpea, Double cropping, Wheat

Introduction

Chickpea (*Cicer arietinum* L.) is an annual grain legume or "pulse crop" that is used extensively for human consumption, market and fertility restoration. According to central statistics agency (CSA, 2015), chickpea production in Ethiopia covers 239,711 ha of land and the productivity was 1.91t/ha. Hence the Amhara region took a share of 124,854 ha, of which 41,787 ha of chickpea production is located in north Gondar zone. The production of chickpea is dominantly distributed in the mid altitude of the zone. The production in the area is mainly done in sole cropping system. Its production takes place with residual moisture planted at the end of August or beginning of September. Both chickpea and wheat share common agroecology on the vertisol of North Western Ethiopia.

Bread wheat is one of the most staple food crops in the world and is one of the most important cereal crop cultivated in Ethiopia. It is also one of the most important crops in Amhara region and has a high potential for the expansion (Alelign, 1988). Bread wheat production is practiced recently in the mid altitude of North Gondar zone and mainly produced entirely as sole cropping.

Double cropping could maximize benefit from same area and season. It is a key to look for best combination and compatibility of crops to exhaust the opportunity from the system. It was reported that double cropping have 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 (Beuerlein, 2001). Legumes are able to fix and incorporate nitrogen into the system and improved soil structure, avoiding the formation of hardpan and promote better aeration. In one of the studies, it was reported that double-cropped wheat and soybean used 54-70% of the annual rainfall; while only 40% of the incident PAR (photosynthetically active radiation) was utilized (Caviglia et al., 2004). From the producers' point of view, double cropping systems increase the value and income of agricultural production. There is no solid evidence documented on the double cropping between wheat and chickpea in Ethiopia. However, as a synonym double cropping of chickpea with wheat has been found to be quite remunerative. For example, it was clearly shown that 50:50 chickpea-wheat mixed cropping gave the highest land-equivalent ratio (Asaduzzamam *et al.*, 1989). Furthermore, a high net return from wheat-chickpea mixed cropping at a ratio of 5:1 was reported (Sharma *et al*., 1987). Even though evidences and promotions are not well advancing, there has been some practices in central parts of Ethiopia where cropping of principal crops (cereals) with precursor (chickpea) using the main cropping season. According to Muluneh *et al*, (2014) concluded that double-cropping of early-maturing, improved forage crops and residual soil moisture-based planting of chickpea and grass pea could improve feed availability, and labor and land productivity.

Mid altitude of North Gondar zone including Dembia, G/zuria and Takusa have a high potential to produce two crops in one cropping season as a double cropping. The rain fall distribution combined with the high retention of vertisol, enables the area to support two crops of high compatibility viz., wheat under full rain fall and chickpea suit for partial phenological residual moisture. The soil in the area has vertic nature with high water holding capacity. However, farmers are still practicing sole cropping because there is neither verified research outputs not awareness created and promotion that support for the practicing of double cropping in the area. It is thus vital and timely to evaluate the feasibility of double cropping in the area, in terms of technical and economic feasibility concept. Therefore, the objective of the experiment was to evaluate the economic and technical feasibility of wheat-chickpea in double cropping combination for improved production system.

Materials and Methods

The wheat-chickpea sequenced experiment was done in two sites (research sites and on farm) at Takusa district during the 2015 cropping season. The trials were laid down in factorial arrangement of randomized complete block design (RCBD) with three replications. Three bread wheat (Senkegna, Tay and Dinknesh) and two chickpea varieties (Habru and Natoli) were used. The plot size of the experiment was 1.8m x 3m (=5.4m^2). Each experimental plot had 9 rows for bread wheat and six rows for chickpea. Planting was 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 DAP fertilizer was applied once at planting. Urea fertilizer, however, was applied in split at planting and tillering stages for bread wheat.

Common agronomic parameters including; 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 were measured based on representative sample of each treatment from both species.

Partial budget analysis was done to compare the financial feasibility of each treatment. Partial budget analysis is the way of calculating the total cost that varies the net benefits of each treatment in an on farm expert (CIMMYT, 1988). The partial budget analysis includes the average yield for each treatment, adjusted yield and gross benefit. All costs that show variation due to the treatment effects were recorded. The major cost items that vary across treatments were seed, fertilizer, labour and draft power. Other cost of production other than cost that varies was similar for all treatments. To calculate the net benefit gained from each treatment, the farm gate grain price of chickpea and wheat, average yield and adjusted yield for each treatment were taken. The adjusted yield is the yield adjusted downward by certain percentage to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. Then dominance analysis was carried out to compare the increase in terms of cost that varies with its respective benefits. Those treatments which have lower net benefits but have higher or the same cost that vary were dominated and rejected from the analysis.

Rainfall distribution

The planting date of the experiment was on June 20, 2015, and all the three bread wheat varieties were planted at the same time. During this time the soil was at field capacity and there was enough moisture for the germination and growth of the wheat crop (see Fig 1, for rainfall distribution).

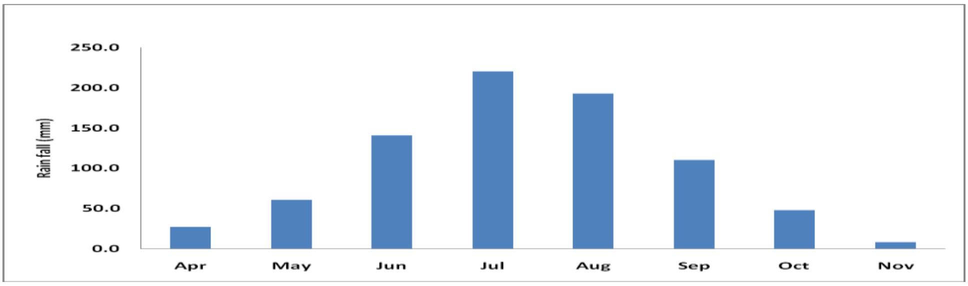

Figure 1. Rainfall in 2015 at Takusa, met station

Results and Discussion

The analysis of variance showed that in all the agronomic parameters such as heading days, maturity days, spike length, number of tiller per plant, thousand seed weight and grain yield; there were significance ($p<0.05$) difference among treatments.

From the three bread wheat varieties tested, variety Dinknesh (with heading days of 53) was found to be much earlier than the other two tested wheat varieties (Table 1). Variety Senkegna and Tay mature lately and both took 97 days to mature, whereas the early maturing bread wheat variety Dinkinesh took 81 days. This parameter (maturity date) have significance effect on effective utilization of natural resources especially water in the double cropping farming system. Hence the subsequent chickpea crop planted immediately after the harvest of the wheat appears to get enough moisture for the growth. Planting time is critical in double-cropping systems as maturity times and dates have greatly affected productivity (Sanford et al., 1973). However, the other two bread wheat varieties mature on October 4-6, 2016, which have weaker compatibility in double cropping concept and affected the productivity of the subsequent chickpea crop.

Table 1. HD, MD, PH, Tiller per plant, Spike length, TSW and Grain yield (Delgi Station) of wheat crop.

Treatment	HD	MD	PH	No.of till	Spike length (cm)	TSW	Yield (kg/ha)
Senkegna	63.3^{b}	96.3^{a}	71.1^{bcd}	5.7^{abc}	7.8^{ab}	25.1^{e}	1211^{c}
Tay	65.6^{a}	96.6^{a}	73.4^{abcd}	3.9^{bc}	8.9^{a}	27.1^{cde}	1153^{c}
Dinknesh	53.0^{c}	82.3^{b}	75.8^{abc}	4.4^{abc}	7.4^{b}	32.7^{ab}	2511^{a}
Senkegn +Habru	64.6^{ab}	97.6^{a}	72.4^{abcd}	6.0^{ab}	7.3^{b}	29.5^{bcde}	1815^{abc}
Tay + Habru	65.6^{a}	98.0^{a}	74.2^{abcd}	6.3^{a}	7.9^{ab}	30.0^{abcd}	1438^{bc}
Dinknesh + Habru	52.6^{c}	82.0^{b}	80.6^{a}	3.60^{c}	7.0^{b}	34.5^{a}	2595^{a}
Senkegna + Natoli	64.6^{ab}	98.0^{a}	69.8^{cd}	6.2^{a}	7.2^{b}	27.9^{cde}	1610^{bc}
Tay + Natoli	65.6^{a}	98.0^{a}	66.0^{d}	5.2^{abc}	7.0^{b}	25.3^{de}	1189^{c}
Dinknesh + Natoli	53.0^{c}	82.3^{b}	78.6^{ab}	5.0^{abc}	7.0^{b}	30.8^{abc}	2123^{ab}
LSD%	1.43	3.40	8.29	2.31	1.26	4.7	844.5
CV%	1.36	2.12	6.50	25.8	9.68	9.42	28.0
LS	**	**	*	*	*	*	*

*Key: *, ** indicate significance at 0.05 and 0.01 probability levels, respectively. LS, Level of Significance, HD, Heading days, MD, Maturity days, PH, Plant height, TSW- thousand seed weight)*

In the tested three bread wheat varieties, variety Dinkinesh gave the tallest plant height (78cm), followed by Tay and Senkegna (Table 1). From the yield determining parameters, variety Senkegna gave high number of tiller per plant compared to other varieties (Table 1). Variety Tay has long spike length (7-8.9 cm) followed by Senkegna (7.2-7.8 cm) and Dinknesh (7-7.4 cm) varieties (Table 1), but variety Dinknesh has higher thousand seed weight (31-34gm) than the other varieties and gave relatively good grain yield ranged between 2.1and 2.59 t/ha.

Similarly variety Dinknesh planted at farm site took shortest days to heading and to mature, when compared with other bread wheat varieties. At on farm Takusa site, there was significance difference between treatments on spike length and thousand seed weight as well. Varieties Tay and Senekegna gave relatively longer spike length than Denknesh. However, Denknesh has high thousand seed weight than the two bread wheat varieties and thus gave highest grain yield in this site (Table 2 and Figure 2).

Table 2. HD, MD, PH, Tiller per plant, Spike length, TSW and Grain yield (Delgi On-farm) of wheat crop.

Treatment	HD	MD	PH	No.of till	Panicle length	TSW	Yield (kg/ha)
Senkegna	61.3^{b}	95.6^{a}	90.5^{ab}	5.9^{ab}	8.4^{a-c}	29.6^{b}	2195^{b}
Tay	61.3^{b}	96.0^{a}	88.2^{a-c}	4.9^{b}	8.2^{a-c}	29.2^{b}	2129^{b}
Dinknesh	49.3^{c}	81.0^{b}	80.6^{bc}	5.8^{ab}	6.8^{c}	36.2^{a}	3337^{a}
Senkegn + Habru	61.3^{b}	97.3^{a}	89.2^{ab}	5.5^{ab}	8.1^{a-c}	31.0^{b}	2585^{ab}
Tay + Habru	63.0^{ab}	96.0^{a}	91.6^{a}	6.5^{ab}	8.6^{ab}	30.2^{b}	2337^{b}
Dinknesh + Habru	49.0^{c}	81.3^{b}	84.5^{abc}	6.8^{a}	6.9^{bc}	36.2^{a}	3264^{a}
Senkegna + Natoli	61.6^{b}	96.6^{a}	86.5^{abc}	6.2^{ab}	7.8^{a-c}	30.5^{b}	2505^{ab}
Tay + Natoli	66.0^{a}	96.6^{a}	91.5^{a}	6.4^{ab}	8.9^{a}	30.8^{b}	2086^{b}
Dinknesh + Natoli	49.6^{c}	81.3^{b}	78.4^{c}	5.3^{ab}	6.7^{c}	35.5^{a}	3294^{a}
LSD%	3.84	1.82	10.4	1.75	1.74	3.3	888
CV%	3.82	1.15	6.93	16.9	12.8	5.93	19.4
LS	**	**	*	*	*	*	*

Key: *, **= *indicate significance at 0.05 and 0.01 probability levels, respectively. LS, Level of Significance, HD, Heading days, MD, Maturity days, PH, Plant height, TSW- thousand seed weight*

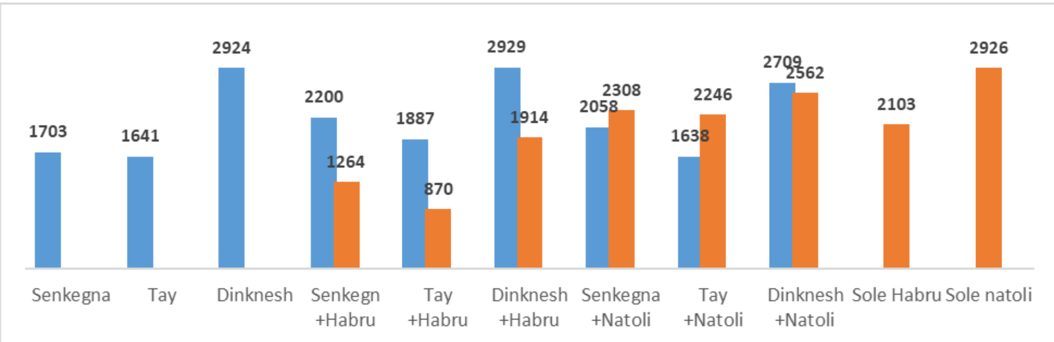

Figure 2. Yield responses (kg/ha) of wheat and chickpea under double cropping pattern

Even if it might be a misappropriate tool for this type of cropping, but for mixed or intercropping, as indices of efficiency we have tried to calculate LER of double crop over monocrop counterparts. LER compares the yields from growing two or more crops together with yields from growing the same crops in monocultures or pure stand. LER calculated as the sum of the fractions of the intercropped yields divided by the sole-crop yield. Based on this LER has fallen between 0.53 and 1.20 for wheat and between 0.41 and 0.91 for chickpea; with total LER value ranging between 0.76 and 1.99. This means a concept in the moisture, radiation and nutrient use efficiency for output maximization, just as high as doubling than sole system counterparts. However, there is time extension for two crops in tandem than sole cropping despite the best compatibility design implemented. A proper efficiency analysis of a cropping system should take the use of the field time into consideration, because increasing the number of component crops or harvests could allow the use of field time, soil and aerial resources more efficiently (Worku, 2014). In another study it was observed that intercrops increased water resource capture compared to the sole counter parts as a result of extended duration of the intercropping system (Coll *et al.,* 2012). Furthermore, in a study aimed to compare two-, three- and four-component intercrops grown together, it was reported that more crops in a mixture are likely to increase the chance for yield advantage and weed suppression (Nelson *et al.,* 2012). Growing two pulse components sequentially under intercropping instead of one could permit to fully utilize the growing season.

The combined analysis of variance showed that, except plant height, all recorded parameter showed significance difference between treatments. Treatment with site interaction did not have significant effect on heading days, maturity days, number of tiller per plant, spike length thousand seed weight and grain yield. There are inconsistencies on scenarios, as many factors interact to affect the recorded parameters at production site. Hence in some cases, it is possible that yield in double cropping could be comparable to sole. In our observation, planting of chickpea immediately after wheat allow the chickpea plant to get sufficient moisture (a more yield determining factor), which might support the above assertion. Combined analysis for parameters in wheat showed common significance values for treatments and sites (Table 3).

Table 3. Combined Analysis of variance of HD, MD, PH, Tiller per plant, Spike length, TSW and Grain yield (at 2 sites) of wheat crop.

Source of variation	HD	MD	PH	No.of till	Spike length	TSW	Yield (kg/ha)
Rep	Ns	Ns	*	Ns	Ns	ns	Ns
Treatment (T)	**	**	Ns	*	*	**	**
Site (S)	**	*	**	*	Ns	**	**
T*S	Ns	Ns	**	Ns	Ns	Ns	Ns

Key: *, **= *indicate significance at 0.05 and 0.01 probability levels, respectively. HD, Heading days, MD, Maturity days, PH, Plant height, TSW- thousand seed weight*)

The combined data also showed that, variety Dinknesh took short days to mature (81 days) when compared to Senkegna (97 days) and Tay (97 days) varieties (Table 4). The shortest spike length was observed on variety Denknesh (8.86cm) whereas the longest spike length obtained on variety Tay (8.58cm). The highest thousand seed weight and grain yield was observed on variety Denknesh and has significant difference at P<0.01with the other varieties (Table 4).

Table 4. Mean grain yield and other agronomic traits of wheat crop

Treatment	HD	MD	PH	No.of till	Panicle length	TSW	Yield (kg/ha)
Senkegna	62.3^{c}	96.0^{a}	80.8	5.85^{a}	8.1^{abc}	27.3^{c}	1703^{c}
Tay	63.5^{bc}	96.3^{a}	80.9	4.4^{b}	8.58^{a}	28.2^{bc}	1641^{c}
Dinknesh	51.2^{d}	81.7^{b}	78.2	5.2^{ab}	7.16^{cde}	34.5^{a}	2924^{a}
Senkegn + Habru	63^{bc}	97.5^{a}	80.8	5.7^{a}	7.3^{abcde}	33^{b}	2200^{bc}
Tay + Habru	64.8^{ab}	97.0^{a}	82.9	6.4^{a}	8.30^{ab}	30.1^{c}	1887^{c}
Dinknesh + Habru	50.8^{d}	81.7^{b}	82.6	5.2^{ab}	6.96^{ed}	35.4^{a}	2929^{a}
Senkegna + Natoli	63.2^{bc}	97.3^{a}	78.2	6.2^{a}	7.50^{bcde}	29.2^{bc}	2058^{bc}
Tay + Natoli	65.8^{a}	97.3^{a}	78.8	5.8^{a}	7.96^{abcd}	28.1^{bc}	1638^{c}
Dinknesh + Natoli	51.3^{d}	81.8^{b}	78.5	5.2^{ab}	6.86^{e}	33.2^{a}	2709^{ab}
LSD%	1.93	1.88	6.38	1.36	1.007	2.84	661
CV%	2.77	1.75	6.78	20.84	11.16	7.88	25.7

Key: **, **= indicate significance at 0.05 and 0.01 probability levels, respectively, HD, Heading days, MD, Maturity days, PH, Plant height, TSW- thousand seed weight*

The two chickpea varieties namely Habru and Natoli used for our experiment, responded differently for double cropping farming system. The analysis of variance in Table 5 showed that there was significant difference in most recorded parameters except plant height.

Table 5. Analysis of variance of Chickpea during the 2015 cropping season.

Source of variation	MD	PH	Pod per plant	Seed per pod	HSW	Yield (kg/ha)
Treatment	**	NS	**	*	*	**
Rep	NS	NS	NS	NS	NS	NS
CV	2.2	10.3	22.1	15.8	4.2	19

Key: **, **= indicate significance at 0.05 and 0.01 probability levels respectively. NS, Non Significance. HD, heading days, MD, Maturity days. HSW- Hundred Seed Weight*)

Sole cropping of chickpea crop took longer maturity days (~ 110 days) than the wheat-chickpea combination, which took nearly 90 days (Table 6). One of the possible reasons for maturity difference is the moisture regime, which triggers the crop to mature fast or to remain vegetative, as chickpea is known with its indeterminate growth habit. Sole planting of Natoli (2926 kg/ha) and Habru (2103kg/ha) chickpea varieties gave relatively higher yield (about double), when compared with their respective double cropping combination. In contrast there is clear distinction trend between sole and double cropping responses in wheat, which is difficult to define as wheat is not expected to suffer from any competition.

Table 6. Analysis of variance of for major traits of Chickpea varieties

Treatment	MD	PH	Pod per plant	Seed per pod	HSW	Yield (kg/ha)
Sole Habru	111[a]	50.1	52.2[abc]	1.26[ab]	28.08[ab]	2103[b]
Senkegn +Habru	90[b]	44.8	42.1[c]	0.9[b]	28.64[a]	1264[cd]
Tay + Habru	89[b]	44.2	51.5[abc]	0.9[b]	27.3[abc]	870[d]
Dinknesh + Habru	110[a]	51.1	54.9[abc]	1.33[a]	29.1[a]	1914[bc]
Sole Natoli	112[a]	48.2	44.4[bc]	1.26[ab]	25.8[c]	2926[a]
Senkegna +Natoli	91[b]	43.4	62.2[ab]	1.53[a]	27.08[abc]	2308[ab]
Tay +Natoli	91[b]	43.6	70.8[a]	1.2[ab]	26.2[bc]	2246[b]
Dinknesh +Natoli	111[a]	45.1	48.3[bc]	1.4[a]	26.58[bc]	2562[ab]
LSD%	3.89	8.42	20.7	0.34	2.05	674
CV%	2.2	10.3	22.1	15.8	4.2	19

The highest grain yield in wheat-chickpea double cropping farming system was obtained from Dinknesh wheat variety (2709kg/ha) with Natoli chickpea variety (2562 Kg/ha) and this combination is recommended for areas having similar agro ecology as Takusa district has for double cropping farming system.

Financial analysis

Partial budget analysis was done to compare the financial feasibility of each treatment. The result of partial budget analysis in Table 7 indicates that lowest cost and benefit was obtained from sole *Habru* chickpea variety while the highest cost and benefit was recorded when *Natoli* chickpea variety was double cropped with *Denekinesh* wheat variety. To do the dominance analysis, the total cost that varies in each treatment with its net benefit was listed in ascending order. Except treatments which contain sole *Natoli* chickpea variety double cropped with *Denekinesh* wheat variety, all other treatments were dominated and rejected from the analysis since the total cost that varies was higher but had relatively lower net benefit.

Table 7. Marginal rate of return of wheat chickpea double cropping system

Treatment	Sole Habru	Sole Natoli	Sole Senkegna	Sole Tay	Sole Dinknesh	Senkegn + Habru	Tay + Habru	Dinknesh + Habru	Senkegna +Natoli	Tay + Natoli	Dinknesh + Natoli
wheat Yield kg/ha	0	0	1703	1641	2924	2200	1887	2929	2058	1638	2709
Adj. yield wheat (kg/ha)	0	0	1532.7	1476.9	2631.6	1980	1698.3	2636.1	1852.2	1474.2	2438.1
Chickpea yield kg/ha	2103	2926	0	0	0	1264	870	1914	2308	2246	2562
Adj. yield chickpea (kg/ha)	1892.7	2633.4	0	0	0	1137.6	783	1722.6	2077.2	2021.4	2305.8
Gross filed benefit	26497.8	36867.6	15327	14769	26316	35726.4	27945	50477.4	47602.8	43041.6	566620.2
wheat production cost birr/ha	0	0	10140	10140	10140	10140	10140	10140	10140	10140	10140
Chickpea production cost birr/ha	4670	4670	0	0	0	4190	4190	4190	4190	4190	4190
TCV (ETB/ha)	4670	4670	10140	10140	10140	14330	14330	14330	14330	14330	14330
NB (ETB/ha)	21827.8	32197.6	5187	4629	16176	213960.4	13615	36147.4	33272.8	287110.6	423320.2
Dominance analysis	D		D	D	D	D	D	D	D	D	
MC (ETB/ha)											9660
MNB (ETB/ha)											101340.6
MRR (%)											104.913

Therefore, marginal rate of return (MRR) was calculated for the two treatments only. The MRR result showed that double cropping of *Natoli* chickpea variety with *Dinknesh* wheat variety had 104% MRR. This means that one birr spending on the treatment (double cropping *Natoli* chickpea variety with *Dinknesh* wheat variety) over sole *Natoli* chickpea variety can cover the cost and have a return of birr 1.04. Therefore, there is a great concern to integrate double cropping as feasible system in the community of agri-practitioners. It is also important to note that, in the era of continuous land fragmentation, cropping system that intensify yield vertically are of great options, to be included in the package for promotion.

Conclusion and Recommendation

Maturity days of both crop varieties have significance effect on the total grain yield. Wheat variety Dinkesh took relatively shortest days to mature, whereas, Senkegna and Tay variety took long days to mature, but variety Dinknesh has short spike length when compared to others. The highest grain yield in wheat-chickpea double cropping farming system was obtained from Dinknesh wheat variety (2709kg/ha) with Natoli chickpea variety (2562 Kg/ha) and this combination is recommended for areas having similar agro ecology with Takusa district for double cropping farming system. This association has the highest biological efficiency, largest total productivity and the optimal monetary return. Thus, the combination will be useful to address both the food requirement and cash needs of farmers. It is also important to note that, in the era of continuous land fragmentation, cropping system that intensify yield vertically are of great options, to be in the technology package and promotion.

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