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Influence of Intercropping Combinations on Growth, Components, Yield, and Quality of Faba Bean and Potato

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ABSTRACT

A two-year (2018-2020) experiment was conducted to determine the optimum intercropping pattern and varietal combination and the compatibility of potato and faba bean in intercropping system. The experiment was arranged in a randomized complete block design of three combinations (Gera×Hachalu, Gera×Dosha, and Gera×Dagim) and four intercropping patterns (1×1, 1×2, 2×1, 2×2) with a 3x4 factorial arrangement and sole crops of faba bean (Hachalu, Dosha, and Dagim) and potato(Gera) as a control. The highest grain yield per hectare (1669.2 kg) was obtained from the Gera×Dosha combination and the intercropping pattern of 1×2 followed by 2×2 with no significant difference between them. The highest marketable tuber yield per hectare (13627 kg) was recorded by the interaction of Gera×Dosha with 2×1 (two rows of potatoes with one row of faba bean) intercropping pattern. This two-year experiment indicated that the best combination of potato and faba bean is Gera with dosha. The best intercropping system is 2x2 (two rows of faba beans with two rows of potatoes). For the growers who want potatoes as the main crop, 2 x1(two rows of potatoes with one row of faba bean) is best and compatible. For the farmers who want to grow faba beans as a main crop 1x2 (one row of potatoes with two rows of faba beans) intercropping system is best. It can be concluded that potato and faba beans are compatible with the intercropping system and farmers can employ different intercropping systems based on their requirements.

Keywords: Faba Bean; Intercropping; Potato; Quality; Varietal Interaction; Yield

Introduction

Intercropping is growing two or more species simultaneously in the same field during a growing season [1]. which is important in crop production and adopted widely in different parts of the world [2]. Biophysical reasons for using intercropping include better utilization of environmental factors, greater yield stability in variable environments, soil conservation practices, and efficient use of resources and labor. Socio-economic reasons such as the magnitude of inputs and outputs and their contribution to the stabilization of household food supply [3,4]. The most common crop mixtures in different parts of the world are, maize/soybean, sorghum/ soybean, maize/faba bean, wheat/chickpea, wheat/faba bean, barley/pea/, maize/potato, Potato/ faba bean, potato/garden pea, etc [5-8]. The most common crop mixtures practiced by Ethiopian farmers in the different parts are, sorghum/ chickpea, sorghum/ faba bean, sorghum/ barley, sorghum/ finger millet, finger millet/rape seed, maize/potato, maize/faba bean, teff/ sunflower, wheat/ barley, pea/horse bean, maize/ rape seed, sorghum/ cowpea, sorghum/ groundnut, etc [9]. Potato is one of the most important root crops which is widely produced across different parts of the world with an average annual yield of 368,168,914 tonnes from 17578672 hectares of land with an average yield of 20.9-t.ha -1. In Ethiopia, the total area covered by potatoes in 2018 was 66,933 ha with a production of 743,153 tonnes and an average yield of 11.1 t.ha-1 [10]. Potato intercropping with cereal, legume, and pulse is practiced in different parts of the world for different production outcomes [11-14]. Faba bean is one of the legumes which is consumed in many countries in

varieties of formulations. Its average yield across the world in 2018 is 30,434,280 tonnes from 34,495,662 hectares [10]. Faba bean is highly suitable for intercropping with different crops in different combinations and production systems [5,7].

Significance of the Study

The intercropping of non-legumes with legumes is the most common practice in different parts of the world mainly by small-scale farmers. This is because legumes fix atmospheric N, sequestering it by immobilizing nitrate-N into plant protein, which provides an appropriate competition to N loss pathways and increases the availability of nitrogen in the soil [15-17].

Aim of the Study

In the North Shewa zone both faba bean and potato are the main crops produced by small-scale farmers with no information on the possibility and impact of intercropping of these crops. Furthermore, the varietal combinations for the production of these crops need to be analyzed. Based on this two-year experiment (2018/2019 and 2019/2020) was conducted at the University of Debre Berhan which was aiming to determine the impact of intercropping and varietal combinations on the yield and quality of component crops, and measure the compatibility of faba beans and potatoes in intercropping.

Materials and Methods

The Study Area

The experiment was carried out during the rainy season at Debre Berhan University agricultural demonstration site which is located at an elevation ranging between 2800 and 2845 m above sea level (masl). It is found in the North Shewa zones of Amhara regional state, a central highland of Ethiopia, and about 130 km from Addis Ababa on the way to Dessie. The area has an average annual rainfall of 927.1 mm and is characterized by a bimodal rainfall pattern with maximum (293.02 mm) and minimum (4.72 mm) peaks in August and December, respectively. In general, the areas fall under the highland (dega) agroecological zone with a frost incidence from October to December. The soil is characterized as dominated by vertosols [18].

Treatments, Experimental Design, and Procedures

The two-year field experiment was conducted in the 2018 and 2019 cropping seasons under the rainfed condition to determine the influence of intercropping type on the yield and quality of inter-cropped potatoes and faba beans. Three varieties of Faba beans (Hachalu, Dosha, Dagim) were intercropped with the Gera variety of potato based on the ratios 1:1 (1-row potato with 1-row faba bean), 2:1 (two rows of potato with 1-row faba bean), 1:2 (1-row of potato with two rows of faba bean), 2:2 (two rows of potato with two rows of faba bean), sole cropping of faba bean (Hachalu, Dosha, Dagim), and sole cropping of Gera potato. A total of 16 treatments were arranged as 4 intercropping types with 3 varieties and 4 sole cropping systems. The plot size was 2.5 × 5 m (12.5 m2) with their replications. The spacing between plots was 1 m and 1.5 between blocks. The treatments were arranged in a randomized complete block design with a factorial scheme. In a 1:1 planting system, faba bean plants were planted in between the rows of potatoes in alternating fashion. In the planting system of 2:2, two rows of potatoes were planted next to two rows of faba beans with a spacing between them of 40 cm. Whereas, in a 2:1 cropping system in which two rows of potatoes with a 1-row of faba beans and a 75 cm spacing. Different from this in a 2:1 system of planting, two rows of faba beans with a 1-row of potatoes were planted, the system was arranged as two rows of faba beans with 40 cm to a 1-row of potatoes.

Land Preparation

The land was well-tilled to a depth of 35 cm and was neatly prepared. The seeds of each of the faba bean and potato varieties were collected from Debre Berhan Agriculture Research Center (DARC). The recommended spacing for faba bean and potato was utilized and the intercropping was laid out in 2:2 ratios. Cultural practices such as weeding, cultivation, ridging, and fertilization were practiced as per the recommendation of DARC. The recommended rate of DAP and Urea fertilizers for potatoes was done in a side dressing near the root system of the plants. The DAP fertilizers were added before planting and the Urea fertilizers were applied in a split week after emergence and before flowering. Hand weeding was done to control weeds and pesticides were applied for pest control.

Data Collected

Growth and yield data of faba bean mainly plant height, number of pods per plant, number of seeds per pod, hundred seed weight (g), seed yield per plot (g), and yield per hectare (kg) were collected. Similarly, growth yield and quality parameters of potatoes mainly, Plant height (cm), marketable and unmarketable tuber number per plot, marketable and unmarketable tuber number per hectare, marketable and unmarketable tuber yield per ha, Marketable and unmarketable tuber yield per plot, Percent tuber dry matter yield and Specific gravity at final harvest specific gravity of tubers were measured as indicated by Murphy [19].

System Productivity: System productivity of the intercropping was determined by calculating the land equivalent ratio (LER) as stated by Willey, [20].

Where Yab= yield per unit area of crop a in a mixture; Yaa= yield per unit area of crop a in sole; Yba= yield per unit area of crop b in a mixture; Ybb= yield per unit area of crop b in sole in another way, the land equivalent ratio can be calculated using the formula: LER= La + Lb.

Data Analysis

The data collected were subjected to analysis of variance (ANOVA) according to the procedure outlined for randomized complete block design (RCBD) using Statistical Analysis Software (SAS), version 9.2 (2009). Detection of differences among treatment means was performed following Duncan's Multiple Range Test at a 5% probability level [21].

Results and Discussion

Intercropping of Faba Bean

Plant Height: The height of the faba bean was highly significantly (p≤0.01) affected by varietal combination and intercropping types (Tables 1-3). The interaction effect of varietal combination and intercropping types was highly significant (p≤0.01) on the plant height of faba bean intercropped with potato (Table 2). The highest plant height (107.2 cm) was recorded by the interaction of Gera×Dosha interactions. Whereas the lowest plant height (79.5 cm) was recorded by the interaction of Gera×Hachalu combination with a 1×2 pattern. This difference could be due to the varietal combination's preference for equal ratios of the intercropping pattern than unequal ratios. Furthermore, it could be also associated with varietal characteristics as Dosha has a high plant size. The highest height was recorded by the interaction of combination with a 2×2 and a 1×1 could be due to less competition for minerals and nutrients between companion crops. In the Hachalu and Dagim varieties of faba bean plant height was taller for sole cropping than intercropping. As for the research report, the mean plant height of the faba bean in the sole crop was higher than intercropping with teff [22]. In Dosha, there was no significant difference in plant height of faba bean between sole and intercropping systems. A similar report describes no significant difference between the sole and intercropping pattern in faba bean plant intercropped with sorghum [23]. The shortest plant heigh recorded by intercropping than sole cropping might be associated with high competition of minerals and nutrients by intercrops than the sole cropped plants. In contrast to this result, different research verified that the vegetative growth mainly plant height and leaf area index are enhanced by intercropping than sole cropping systems [24,25].

Table 1: Treatment combinations and arrangement of potatoes and faba beans.

Treatment Number	Spatial Arrangement of Potato and Faba Bean	Treatment Layout:
1	1:1	Gera× Hachalu
2	1:1	Gera× Dosha
3	1:1	Gera× Dagim
4	1:2	Gera× Hachalu
5	1:2	Gera× Dosha
6	1:2	Gera× Dagim
7	2:2	Gera× Hachalu
8	2:2	Gera× Dosha
9	2:2	Gera× Dagim
10	2:1	Gera× Hachalu
11	2:1	Gera× Dosha
12	2:1	Gera× Dagim
13	control	Hachalu
14	control	Dosha
15	control	Dagim
16	control	Gera

Table 2: Interaction effect of varietal combination and intercropping pattern on growth and yield of faba bean grown at Debre Berhan.

Plant Height(cm)				
	Cropping Pattern			
Varietal combination	1×1	1×2	2×1	2×2
Gera×Hachalu	94.4bcd	79.5e	99.9abc	92.8bcd
Gera×Dosha	99.4abc	103.3ab	94.2bcd	107.2a
Gera×Dagim	83.8de	79.9e	87.2de	91.1cd
Sig. level	**			
CV (%)	8.9			

Note: Sig. level = significant difference at P=0.05, CV (%) = Coefficient of variation ns= non-significant. Means in columns with the same letter(s) in each treatment are not significantly different.

Table 3: Main effect of varietal combination and intercropping pattern on growth and yield of faba bean grown at Debre Berhan.

Varietal combination	Plh(cm)	No pod/plt	N seed/pod	100 seed/wg t/g	Yld/pl/g	Yld/ha/kg	Ler
Gera×Hachalu	91.6b	21.3b	3.21	61.9b	1772.1b	1361.6b	0.47
Gera×Dosha	101.05a	25.6a	3.27	69.4a	2329.4a	1669.2a	0.54
Gera×Dagim	85.5c	25.08a	3.19	35.6c	1873.9b	1398.6b	0.52
Sig. level	**	*	ns	**	*	**	ns
CV (%)	8.1	22.4	6.1	8.5	37	19.5	33.9
Intercropping Pattern							
1×1	92.5ab	24.4ab	3.28	54.7ab	2095.2a	1711.9a	0.6a
1×2	88.7b	27.3a	3.27	57a	2385.7a	1708.6a	0.57
2×1	92.7ab	21.4b	3.21	52.8b	1240.3b	841.7b	0.55
2×2	97.0a	22.8b	3.14	58.0a	2245.9a	1643.6a	0.31b
Sig. level	**	**	ns	**	**	**	**
CV (%)	8.1	22.4	6.1	8.5	37	19.5	33.9

Note: Sig. level = significant difference at P=0.05, CV (%) = Coefficient of variation ns= non-significant. Means in columns with the same letter(s) in each treatment are not significantly different.

Number of Pods Per Plant: The number of pods per plant was highly significantly (p≤0.01) affected by intercropping types. The varietal combination also significantly affected the number of pods per plant (Table 4). However, the number of pods per plant doesn't show a significant difference between sole-cropped and intercropped faba beans in all varieties. The highest number of pods per plant (27.3) was recorded by the intercropping pattern of a 1×2 (1-row of potato with 2 rows of faba beans) followed by a 1×1 with no significant difference between them. This could be associated with the number of plants per given area of the intercropping pattern, as these intercropping patterns have the highest area coverage than others. Furthermore, this could be due to the high light absorption flux of faba beans in these intercropping patterns. In agreement with this result, (Abd El-Lateef, et al. [26]) reported that a 1:3 (1maize with 3 cowpeas) intercropping pattern of cowpea with maize gave high light flux which increases light absorption in such intercropping. The lowest number of pods per plant was recorded by a 2×1 (2 rows of potatoes with one row of faba beans) intercropping system.

Table 4: Interaction effect of varietal combination and intercropping pattern on growth and yield of faba bean grown at Debre Berhan.

Hundred Seed Weight(Gm)				
Cropping Pattern				
Variety combination	1×1	1×2	2×1	2×2
Gera×Hachalu	61.1bc	61.5bc	56.5c	68.5ab
Gera×Dosha	66.5ab	72a	70a	69.1ab
Gera×Dagim	36.6d	33.5d	36d	36.3d
Sig. level	**			
CV (%)	11.4			

Note: Sig. level = significant difference at P=0.05, CV (%) = Coefficient of variation ns= non-significant. Means in columns with the same letter(s) in each treatment are not significantly different.

The decrease in the number of pods per plant in a 2×1 intercropping could be due to the small area coverage of the faba bean plant and stiff competition for minerals and nutrients with the potato plant. The higher number of pods per plant was also recorded by the varietal interaction of Gera×Dosha followed by Gera×Dagim with no significant difference between them. The difference in the number of pods per plant due to different varietal combinations will be associated with differences in the characteristics of varieties. In agreement with this result, Thole, [27] reported that soybean varieties significantly affected the number of pods per plant while intercropping with maize. This result was in disagreement with (Agegnehu, et al. [28]) who reported that intercropping of faba bean

with barley had a non-significant effect on the number of pods per plant. Similarly, in contrast to this research results, [29] reported that there is a significant difference between sole and intercropping of faba beans in which the highest number of pods is recorded by intercropped faba beans than sole cropping. Thus, intercropping had a positive impact on the number of pods per plant than sole cropping.

Number of Seeds Per Pod: Varietal combination, type of intercropping, and their interaction did not significantly influence the number of seeds per pod of faba beans (Table 5). There was no significant difference in the number of seeds per pod between intercropping and sole cropping of the faba beans. It means in both cases the variation in varietal combination and cropping pattern did not have a significant impact on the number of seeds per pod. This could be implied that the number of seeds per pod is not influenced by management systems but rather genetically. This result is in agreement with Bekele, [30] and Solomon et al. [31] who found that the number of seeds per pod was not significantly affected by intercropping patterns as well as varieties.

Table 5: Impact of cropping pattern on growth and yield of faba bean grown at Debre Berhan.

	Plh(cm)	No pod/plt	N seed/pod	100 seed/wgt/g	Yld/pl/g	Yld/ha/kg	Ler
Sole dagim	96.3a	21.7	3.4	37.6	2732.6a	2628.3a	1
Intercrop dagim	85.5b	25.0	3.1	35.6	1873.9b	1398.7b	0.52
Sig. level	*	ns	ns	ns	*	**	**
CV (%)	10.5	23	7	10.1	45	30	27.9
Sole Dosha	96	22.7	3.3	56.3b	3725a	3417.5a	1
Intercrop Dosha	101	25.6	3.27	69.4a	2329b	1669.3b	0.54
Sig.level	ns	ns	ns	**	**	**	ns
CV (%)	8.1	29	5.2	12.2	41.4	27	
Sole hachalu	104a	23.3	3.2	61.9	4582.2a	3609.2a	1.0
Intercrop hachalu	91.6b	21.3	3.2	61.8	1772.1b	1361.6b	0.47
Sig. level	**	ns	ns	ns	**	**	**
CV (%)	11	27.6	6.1	10.6	30.5	21.3	23.2

Note: Sig. level = significant difference at P=0.05, CV (%) = Coefficient of variation ns= non-significant. Means in columns with the same letter(s) in each treatment are not significantly different.

100 Seed Weight: Hundred seed weight was highly significantly ($p \leq 0.01$) affected by both the main and interaction effect of intercropping types and varietal combinations (Tables 3 & 4). The highest hundred seed weight was recorded by the interaction of Gera×Dosha varietal combination with a 1×2 intercropping system (1-row Gera with 2 rows of Dosha) followed by the same varietal combination with a 2×1 intercropping system (2 rows of Gera with one row of Dosha) and with no significant difference to Gera×Hachalu combination interacted with a 2×2 intercropping system. The lowest hundred seed weight was recorded for the interaction of the Gera×Dagim combination with a 1×2 intercropping system. This result is in agreement with (Richard, et al. [32]) who found that varieties significantly affected hundred seed weight. The main effect factor showed that the highest hundred seed weight was recorded by the Gera×Dosha combination and by a 1:2 intercropping system. The difference by combination could be due to the varietal character of faba beans with the ability of each variety to exploit the available natural resources. Among cropping systems there was a highly significant difference between sole and intercropping systems for The Dosha variety. But a non-significant difference was recorded between sole and intercropping systems for both Dagim and Hachalu varieties. (Solomon, et al. [31]) reported that there was no significant difference between sole and intercropping patterns. But the result of this study is in contrast to Bekele [30] who reported that there was a significant difference in hundred seed weight between sole and intercropping patterns.

Yield Per Plot: Yield per plot was significantly ($P<0.05$) affected by varietal combination and highly significantly influenced by intercropping systems. The highest yield per plot of (2.3 kg) was recorded by a varietal combination of Gera and Dosha. Whereas the lowest, which is 1.7 kg was recorded by a varietal combination of the Gera variety of potato with The Hachalu variety of faba bean (Table 3). The intercropping system of 1×2 (1-row Gera with 2 rows of Dosha) gave the highest yield per plot of 2.38 kg. The lowest was recorded by 2×1 (2 rows of Gera with one row of faba bean) intercropping system. This could be attributed to the land size proportion difference between those two intercropping patterns. This research result

coincides with (Agegnehu, et al. [28]) who reported that an increase in the proportion of faba beans from 12.5 to 62.5% increased faba bean yields from 21 to 72%. Adafre [33] and Gutu, et al. [34] also confirmed that varieties and intercropping systems significantly affected the grain yield of intercropped soybean and faba bean plants respectively. A highly significant difference in yield per plot was recorded between the sole and intercropping patterns in Dosha and Hachalu varieties, but a significant difference was recorded for Dagim Variety. In all cases, sole cropping was superior to intercropping for yield per plot, which might be because of high intercrop competition for growth resources in intercropping sole cropping, especially for soil moisture. This result was in agreement with (Agegnehu, et al. [12,28,33]), who concluded that sole cropping gave a higher yield than intercropping systems. In contrast to this result, Tesfaye Tesfaye [35] reported that there was no significant difference in grain yield between the sole and intercropping patterns.

Yield Per Hectare: Sole cropped faba bean showed highly significantly (P<0.01) higher yield than intercropping for all varieties (Dosha, hachalu, Dagim) (Table 3). The main effect of the varietal combination and the intercropping system was highly significant (P<0.01) on yield per hectare of faba bean (Table 3). But there was no significant impact recorded by the interaction of varietal combination and intercropping systems. The highest yield per hectare (1669.2 kg) was recorded by a varietal combination of the Gera variety of potato with the Dosha variety of faba bean. Whereas, the lowest (1361.6 kg) was recorded by the varietal combination of Gera and hachalu. In agreement with this result (Gutu, et al. [34,36,37]), varieties affected yield per hectare of legumes intercropped with other crops. In contrast with the result, the report by Bekele [30] concluded that the impact of varieties in the intercropping system is not significant. The highest yield (1708.6 kg) was recorded by the intercropping system of 1×2 (1-row of The Gera intercropped with 2 rows of faba beans) followed by a 1×1 intercropping system.

The lowest grain yield per hectare (841.7 kg) was recorded by the intercropping system of a 2×1 (2 rows of Gera intercropped with 1 row of faba bean). The yield of faba bean in 1×2 is 51% higher than the intercropping system of 2×1. The possible reason could be the number of rows per hectare of 2×1 intercropping is lower than the 1×2 intercropping pattern which decreases grain yield per hectare. The study of (Gutu, et al. [34]) agreed with this research result which indicated that the haricot bean intercropping pattern of 1:2 spatial arrangements gives higher grain yield than others. In addition, Molla [38] and (Mbah, et al. [39]) reported that higher grain yield per hectare was recorded by a higher planting density in intercropping. This could verify that a greater number of plants per unit area produced a greater yield per hectare. The highest yield by sole cropping than intercropping could be attributed to the reduced interspecific competition between companion plants. Furthermore, it could be associated with a large number of plants per hectare in sole cropping than intercropped faba bean. (Abd El-Lateef, et al. [26,40,41]), agreed with this research result.

Potato Component

Plant Height: Plant heights of potatoes were not significantly affected by the main effect of the varietal interaction of potato and faba beans (Table 6). Whereas the main effect of intercropping type was significant on the plant height of potatoes. Varietal interaction and intercropping pattern were not significantly interacted to affect plant height. The tallest (61.8 cm) plant was recorded by the intercropping pattern of 2×2 followed by 1×1. The shortest plant height was recorded in 1×2 (58.1 cm) in which faba beans are the main crop (Table 6).

Table 6: Interaction effect of varietal combination and intercropping pattern on growth and yield of potato grown at Debre Berhan.

Number of Primary Branches				
Variety Combination	Cropping Pattern			
	1×1	1×2	2×1	2×2
Gera×Hachalu	4.05ab	5.1ab	3.8ab	5.2a
Gera×Dosha	5.98a	4.15ab	5.15a	5.63a
Gera×Dagim	4.06ab	4.6ab	3.0b	5.6a
Sig. level	*			
CV (%)	32.9			

Note: Sig. level = significant difference at P=0.05, CV (%) = Coefficient of variation ns= non-significant. Means in columns with the same letter(s) in each treatment are not significantly different.

The significant impact of intercropping on plant height could be due to root length density in upper soil which can enhance mineral and nutrient absorption [42]. It could also be the efficiency in absorbing solar radiation in the intercropping pattern. It was verified that in intercropping the absorbed radiation very higher [43]. The present result is in agreement with Bindera [44] who reported increased plant height with intercropping patterns. The shortest plant height recorded by the intercropping pattern of potato as a major crop (2×1) and faba bean (1×2) as a major crop could be due to the intra and inter competition for minerals and nutrients. The result of this research indicated that there was a significant difference between intercropping and sole cropping patterns. The tallest plant was recorded by sole cropping than the intercropping pattern. This could be due to the less interspecific competition between component crops. However, this finding is contradictory to the finding of Kuruppuarachchi, [45] who stated that potatoes were taller under intercropped than under sole cropped.

Number of Primary Branches: The interaction effect of the varietal combination and the intercropping pattern was significant ($p<0.05$) on the number of primary branches of potatoes. It was also significantly ($p<0.05$) affected by the main effect of varietal combination and highly significantly ($p<0.01$) affected by the main effect of intercropping systems (Tables 5 & 6). The highest number of primary branches (5.98) was recorded by the interaction of the Gera×Dosha varietal combination and 2×2 intercropping system. The lowest (3.0) was recorded by the interaction of Gera×Dagim and 2×1 intercropping system. Intercropping system 2×2 interreacted with all varietal combinations gave the highest number of primary branches than other intercropping systems. This could be the due to the positive impact of intercropping on effective water use [46]. It could also be due to reduced interspecific and intraspecific competition between component crops in this intercropping system. In agreement with this research different authors [47,48], confirmed that intercropping significantly affected the number of primary branches. There was a significant difference in the number of primary branches by cropping systems. From cropping systems, sole cropping gave the highest number of primary branches than the intercropping pattern. This could be due to below and above-ground competition between component crops in intercropping than sole cropping [49]. This conforms with Ijoyah & Jimba [50] the finding of who found that the number of primary branches was higher by sole cropping than by intercropping, but, in disagreement with this result [51] reported that intercropping gave a higher number of branches than sole cropping.

Average Tuber Weight Per Hill: This parameter responded highly significantly ($p<0.01$) to the varietal combination (Table 6). But, the effect of intercropping types and their interaction with the varietal combination was not significant ($p\geq0.05$). Average tuber weight was higher in the varietal combination of Gera×Dagim followed by Gera×Hachalu with no significant difference between them. The lowest was recorded by the varietal combination of Gera×Dosha. This could be due to the canopy characteristics of faba bean varieties on potato average tuber yield. Gera variety of potato intercropped with dosha variety (have higher canopy size characteristics) gave lower average tuber weight than the others. The average tuber weight to intercropping was higher than sole cropping. In agreement, (Asl, et al. [51]) reported that a higher average tuber weight is obtained in intercropping than in sole cropping.

Table 7: Main effect of varietal combination and intercropping pattern on growth and yield of potato grown at Debre Berhan.

Varietal Combination	Plh(Cm)	Pr.Br	Av T. Weight(Gm)	Spg/Mar	Mar/ Plo(G)	Mar/Ha (Kg)	Unmar/Pl (Gm)	Unmar/Ha (Kg)	Dry%	LER
Gera×Hachalu	61.3	4.5ab	140.2ab	0.4	9910	7928.8	3.75	3004.4	32.7	0.46
Gera×Dosha	58.4	5.2a	122.8b	0.3	10910	9240.8	4	3055.2	33.7	0.53
Gera×Dagim	57.7	4.3b	163.5a	0.3	10219	9224.4	3.6	2885.4	32.6	0.53
Sig. level	ns	*	**	ns	ns	ns	ns	ns	ns	ns
CV (%)	11.1	26.4	31.1	32.1	37.1	34.2	81.5	83.5	12	36.9
Intercropping Pattern										
1×1	60.4	4.69ab	143.98	0.35ab	10683b	9212b	4.1b	3288b	33.3	0.53b
1×2	56.2	4.62ab	128.49	0.29b	6164c	5287c	2.7b	2151b	31.8	0.29c
2×1	58.1	4.03b	145.47	0.43a	14333a	11662a	4.1b	3302b	34.3	0.67a
2×2	61.8	5.4a	150.87	0.41a	10205b	9031b	4.1b	3184b	32.7	0.53b
Sig. level	*	**	ns	**	**	**	ns	ns	ns	**
CV (%)	10.6	25.2	31.1	32.6	40.3	31.6	75.9	77.4	12.63	33.1

Note: Sig. level = significant difference at P=0.05, CV (%) = Coefficient of variation ns= non-significant. Means in columns with the same letter(s) in each treatment are not significantly different.

Specific Gravity (SG): The specific gravity of potatoes was highly significantly ($p<0.01$) affected by the interaction of varietal combination and intercropping system. The main effect of the intercropping pattern was highly significant on specific gravity. Whereas, the effect of the varietal combination on specific gravity was non-significant (Table 7). The highest amount of specific gravity was recorded by the interaction of the Gera×Dagim varietal combination with a 2×1 intercropping pattern with a no-significant difference to the Gera×Dosha varietal combination with the 2×2 intercropping pattern. The reason could be a higher amount of starch accumulation in this intercropping pattern. But the lowest specific gravity was recorded by the interaction of Gera×Dagim with a 1×2 varietal combination. From cropping patterns intercropping patterns gave higher specific gravity than sole cropping. But, this result is in contrast to Getachew [52] who reported that specific gravity is higher in sole cropping than in intercropping. The principle of specific gravity depends on starch makes up about 70% of total tuber solids. Starch is heavier than water, and, therefore, it is the primary determinant of density, which is commonly referred to as tuber-specific gravity. Normally specific gravity readings vary from about 1.055 to 1.095. These readings correlate with 16.5% dry matter to 24% dry matter [53]. In contrast (Singh, et al. [54]) reported that specific gravity is not affected by intercropping.

Marketable, Unmarketable Tuber Weight Per Plot: The main effect of intercropping pattern highly significantly ($p<0.01$) affected marketable yield per plot of potato. The main, as well as the interaction effect varietal combination, was not significant on marketable and unmarketable tuber yield per plot. The intercropping pattern doesn't significantly affect unmarketable tuber yield per plot of potato (Table 6). However, highly significant ($p<0.01$) differences were recorded between the sole and intercropping patterns on marketable and unmarketable yield per plot (Table 7). The highest marketable yield per plot was recorded by the intercropping pattern of 2×1 (2 rows of potatoes with 1 row of faba bean) which is potato as the main crop. Whereas, the lowest marketable yield was recorded by 1×2 (1-row of potato with 2 rows of faba bean) intercropping patterns. The yield per plot of 2×1 intercropping is 43% higher than a 1×2 intercropping pattern. The higher yield recorded by a 2×1 intercropping pattern than the others could be associated with higher area coverage by this intercropping. In addition, the intercropping system may enhance the water use efficiency, light interception ability, and mineral utilization of the potato crop [55,56]. In agreement with this, (Kidane. et al. [55-57]) reported that intercropping pattern of 2×1 gave a higher yield than other intercropping patterns in potatoes and maize intercropping. But, in contrast, Bantie [58] reported that the highest yield was recorded by a 1×1 rather than a 2×1 intercropping.

Table 8: Interaction effect of varietal combination and intercropping pattern on growth and yield of potato grown at Debre Berhan.

Spg/mar				
Variety Combination	Cropping Pattern			
	1×1	1×2	2×1	2×2
Gera×Hachalu	1.04abc	1.044ab	1.039abc	1.04abc
Gera×Dosha	1.032bcd	1.026cd	1.035bc	1.052a
Gera×Dagim	1.034bc	1.017d	1.056a	1.03bcd
Sig. level	**			
CV (%)	33.7			

Note: Sig. level = significant difference at P=0.05, CV (%) = Coefficient of variation ns= non-significant. Means in columns with the same letter(s) in each treatment are not significantly different.

Table 9: Interaction effect of varietal combination and intercropping pattern on growth and yield of potato grown at Debre Berhan.

	Mar/ha/kg			
Variety Combination	Cropping Pattern			
	1×1	1×2	2×1	2×2
Gera×Hachalu	7297cde	5067e	12160ab	7192cde
Gera×Dosha	9690abcd	5594de	13627a	8052bcde
Gera×Dagim	10650abc	5200e	9200bcde	11847ab
Sig.level	**			
CV (%)	36.			

Note: Sig. level = significant difference at P=0.05, CV (%) = Coefficient of variation ns= non-significant. Means in columns with the same letter(s) in each treatment are not significantly different.

Table 10: Effect of cropping pattern on growth and yield of potato grown at Debre Berhan.

Parameters	Sole Cropping	Intercropping	Sign. Level	CV%
Plh (cm)	66.6	59.18	*	13.3
Pr.br (no)	6.01	4.71	*	29.5
Avrg.tw(gm)	126.6	148.5	*	15
Spg/mar	1.021	1.037	**	40.6
mar/plo(kg)	18164	10346	**	49
Mar/ha (Kg)	17401	8798	**	42.3
Unmar/plo(kg)	6.9	3.7	**	73.9
Unmar/ha	5672	2982	**	75.8
Dry%	36.3	33	**	11.3
LER	1	0.5	**	44

Note: Sig. level = significant difference at P=0.05, CV (%) = Coefficient of variation ns= non-significant. Means in columns with the same letter(s) in each treatment are not significantly different.

Marketable and Unmarketable Tuber Yield (kg ha-1): The interaction effect of intercropping pattern and the varietal combination was highly significant ($p<0.01$) on the marketable yield of potatoes (Table 8). A high significant difference was recorded by the intercropping pattern on the marketable yield of potatoes. But the main effect of the varietal combination was not significant (Table 6). The research result indicated that both the main and interaction effect of the varietal combination and intercropping pattern didn't affect the unmarkable tuber yield of potatoes (Tables 8-10). The highest marketable tuber yield (13627 kg.ha-1) was recorded in the Gera×Dosha varietal combination interacted with a 2×1 intercropping pattern with no significant difference with the Gera×Hachalu varietal combination with a 2×1 intercropping pattern. The lowest marketable yield was recorded by the Gera×Hachalu interaction with a 1×2 intercropping pattern followed by the Gera×Dagim varietal interaction with a 1×2 intercropping pattern. The yield difference between the highest and the lowest marketable yield is 63% higher. The yield difference between the two could be due to the decreased inter and intraspecific competition between potato and faba bean; which resulted from the low plant density of faba bean plants per unit area that allowed potato plants to get a greater domain, which is needed for enhanced yield performance. Similar to the present finding a significant increase in marketable tuber yield by intercropping pattern was reported by different researchers [57,59,60-62]. But in contrast to this report, the finding of (Takim, et al. [63]) reported that significant impact of intercropping on unmarketable yield than the marketable yield of sweet potato. From the cropping systems, sole cropping gave the highest marketable yield per hectare than intercropping. This result is in agreement with (Kidane, et al. [57,58]) who reported that sole cropping gave a higher yield than intercropped potato.

Dry Matter Percentage (%): The dry matter percentage of potatoes was not significantly affected by both the main or interaction effect of varietal combination and intercropping pattern (Table 6). Dry matter percentage was highly significantly ($p<0.01$) affected by cropping systems. The higher dry matter percentage was recorded by sole cropping than intercropping. This result finding is in agreement with (Gitari, et al. [42]) who reported that there is a significant effect on the dry matter percentage of potatoes by intercropping systems. According to their report, the highest dry matter percentage was recorded in sole cropping than in intercropping. The result of this research is in disagreement with the reports of different researchers who confirmed that the dry matter percentage of potatoes was significantly affected by intercropping systems [64,65,56].

Productivity of Intercropping: The yield (kg/ha) of faba bean varieties (Hachalu, Dosha, Dagim) in sole cropping was higher than in intercropping (Table 6). The total yield of each variety in sole cropping could be due to the large area of land and the higher number of plants per hectare by sole cropping. The partial Land Equivalent Ratio (LER) of each variety was calculated by dividing intercrops with the respective average sole crop yield and the sum of the partial LER of each component crop gave the total LER (Mead and Willey, 1980). The partial Land Equivalent Ratio (LER) of faba beans for Gera Hachalu and Dagim varieties was highly significant ($P<0.01$), but that of Dosha was not significantly different. The highest partial LER of 0.54 was recorded by potato intercropped dosha varieties of faba bean. Whereas, the lowest partial LER was recorded by potato intercropped with dagim variety. The main effect of the varietal combination was not significant on the LER of faba bean. There were no significant differences in partial LER between varietal combinations of faba bean. Whereas, there was a highly significant difference in partial LER by intercropping patterns. The highest LER was recorded by

the intercropping pattern of 1×2 (one-row potato with two rows of faba bean). But the lowest partial LER was recorded by a 2×1 (two rows of potato with one row of faba bean) intercropping pattern. The higher LER by a 1×2 intercropping pattern and the lowest by a 2×1 intercropping pattern could be associated with the amount of area coverage. The result also indicated that in potato crops the highest LER was recorded by the intercropping pattern of 2×1 (two rows of potatoes with one row of faba bean) and the lowest by 1×2 intercropping patterns. The highest LER was also recorded by sole cropping than intercropping systems. In conformity with this (Kidane, et al. [57,63,65]) reported that sole cropping has higher LER(than intercropping.

Conclusion

The results of this research indicated that varietal combination highly significantly ($P<0.01$) affected hundred seed weight and yield per hectare and significantly affected plant height, number of pods per plant, hundred seed weight, yield per plot and hectare, and land equivalent ratio of faba bean intercropped with potato. Potato crop intercropped with faba bean plant was significantly affected by varietal combination on the number of primary branches. The intercropping pattern significantly affected the number of primary branches, specific gravity, marketable yield per plot, marketable yield per hectare, and land equivalent ratio. The interaction effect of varietal combination and the intercropping pattern was significant on plant height, highly significant on hundred seed weight of faba bean and primary branch number, and specific gravity of potato marketable yield per plot and hectare. There was a significant difference between sole and intercropping on plant height, yield per plot o dagim variety of faba bean, highly significant difference in yield per hectare and land equivalent ratio. According to the two-year experiment, the best varietal combination of potato and faba bean is the Gera with hachalu. The best intercropping system is the 2x2 (two rows of faba beans with two rows of potatoes. For the growers who want potato as a main crop 2 x1(two rows of potatoes with one row of faba beans) is best and compatible. For the farmers who want to grow faba bean as the main crop in potato faba bean intercropping, a 1x2 (one row of potato with two rows of faba bean) intercropping system is preferred. Generally, it can be concluded that potato and faba beans are compatible with intercropping system and farmers can employ different intercropping systems based on their requirements.

Data Availability Statement

Data will be available on request to the corresponding author.

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Competing Interests

Authors have declared that no competing interests exist.

Authors' Contributions

This work was carried out in collaboration among all authors. Author GAK wrote, designed and implemented the research. Authors TK and BD also involved in research design, editing and data collection. All of the authors have read and agreed to the published version of the manuscript.

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