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Investigation of self-productivity in some olive cultivars grown under Antalya ecological conditions

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ABSTRACT

Irregular fruit yield in olives is caused by ecology, cultural processes as well as self-inefficiency and not choosing suitable pollinators. Since the self-productivity of olive varieties in different growing areas, this research was carried out to determine the productivity of 'Gemlik', 'Manzanilla', 'Memecik', 'Nizip Yağlık' and 'Tavşan Yüreği' with high commercial value. Selfing and natural pollination were determined in the Akdeniz University Faculty of Agriculture Research and Application Field in Antalya. In self-pollination, the flowers on the clusters were placed into cloth bags at the balloon stage, the pollen was poured into the pouch at the time of flowering, the pouch mouth was closed with a rope and the pouch was shaken to pollinate. Significant differences were determined in % fruit set rates obtained in varieties as a result of selfing and natural pollination. In all olive cultivars used in the experiment, the percentage of fruit obtained from free pollination was higher than self-pollination. 'Gemlik' and ‘Tavşan Yüreği' were found to be self-fertile, 'Memecik' and 'Nizip Yağlık' were found to be partially productive, and 'Manzanilla' were found to be self-inefficient. The highest fruit set in both free and selfing was determined in the 'Tavşan Yüreği' cultivar.

1. Introduction

Olive, which has an important role in the field of industry, contributes to human health as well as its contribution to the country's economy. Likewise, olive is a valuable plant that provides economic income as well as being an important food source for the people of the region where it is grown. Although there are numerous species and subspecies within the genus Olea, the olive (*Olea europaea* L.) fruit is the only one whose fruit is edible. The majority of olive cultivars have 2n= 46 chromosomes (Falistocco and Tosti 1996; Mineli et al. 2000; Mete 2009).

Self-productivity in olive varieties differs from year to year and according to different ecologies, and this is due to factors such as lighting, temperature, flower bud formation and climatic conditions during flowering (Antognozzi et al. 1978; Singh et al. 1980; Bini et al. 1981; Bartolini and Guerriero 1995; Ugrinovic et al. 1996; Farinelli et al. 2006).

Olive production per unit area in Turkey is low compared to countries such as Spain and Italy (Gül 2020). Inappropriate land conditions, cultural practices such as pruning, irrigation, fight against diseases and pests and fertilization cause low yields and changes in the severity level of alternate-bearing. Another reason for the low yield is that the fertilization biology of the cultivars being cultivated is not exactly known or the information obtained on this subject is not applied in practice (Kaynaş et al. 1998; Gözel et al. 2008; Mete 2009; Tutar 2010; Türkay 2014). In studies on the fertilization biology of olives, researchers have grouped olive varieties into three groups: self-fertile, partially self-fertile and self-infertile (Zapata and Arroya 1978; Moutier 2002).

The inflorescences in olives are formed in groups of 3-5 on the shoot, and the cluster can have between 10 and 40 flowers depending on the environmental conditions, physiological conditions and variety characteristics. Flowering takes place between April and May, depending on the variety and climatic conditions (Lavee 1996; Kaymak 2011). It was determined that the pollen tubes of the self-infertile olive cultivars develop very slowly and most of them cannot reach the embryo sacs (Porlingis and Voyiatzis 1976). It has been determined that pollen tubes develop faster and reach the ovules when there is foreign pollination in olives, while pollen tubes develop slowly in self-pollination and cannot reach the ovules for fertilization (Cuevas and Polito 1997).

In the 'Yamalak Sarısı' olive variety grown in Aydın province, fruit set was 0.09% in selfing and 0.28% in free-pollination, and it was determined that the variety was partially self-fertile (Kaya and Tekintaş 2006).

In the study conducted on 150 olive cultivars in Italy, 8 cultivars were determined to be absolutely self-incompatible, and the rate of fruit set obtained from free pollination applications was found to be higher than in self-pollination applications. It was emphasized that appropriate pollinator use is necessary, including varieties that are thought to be self-compatible (Lombardo et al. 2006).

'Domat' (Mete 2009) and 'Gemlik' olive cultivars were found to be partially self-fertile (Çavuşoğlu 1970; Sütçü 1983), and 'Kilis Yağlık' cultivars were found to be self-productive (Mete and Çetin 2017).

In self-pollination, fruit set rates of 0.95% in 'Lastovka' variety, 1.38% in 'Leccino' variety, 2.16% in 'Levantinka' variety and 1.11% in 'Oblica' variety were determined. The highest fruit set rates in cross-pollination were 7.15% in 'Lastovka x Levantinka', 7.18% in 'Leccino x Oblica', 6.91% in 'Levantinka x Lastovka' and 3.96% in 'Oblica x Lastovka'. The results revealed the necessity of having a pollinator variety in the olive orchard facility (Vulletin Selak et al. 1994). Although the 'Hayat' olive cultivar is self-fertile, it has been determined that the use of 'Ayvalık', 'Memecik' and 'Gemlik' cultivars as pollinators increases productivity (Mete et al. 2016).

The cultivars 'Arbequina', 'Bouteillan' and 'Koroneiki' were found to be self-infertile in Egypt. 'Koroneiki' for 'Arbequina', 'Arbequina' for 'Bouteillan', and 'Bouteillan' for 'Koroneiki' were found to be suitable pollinators (El-Hady et al. 2007).

In Iran, 'Zard' and 'Fishomi' olive cultivars were found to be self-fertile, while 'Roghani' and 'Shiraz' olive cultivars were found to be unproductive (Taslimpour and Aslmoshtaghi 2013).

The effects of selfing, emasculation, pollinator cultivars ('Manzanilla', 'Kalamata' and 'Koroneiki') and free pollination on fruit set were investigated in the 'Picual' olive cultivar. There was no fruit set in emasculation application, the highest fruit set rate was obtained from free pollination (Atawia et al. 2016).

In different regions of Serbia, 1.45% fruit set was obtained in free pollination and 0.1% fruit set in 'Arbequina' cultivar (Lazovic et al. 2017).

In Şanlıurfa, 'Yuvarlak Halhalı' cultivar was self-infertile, 'Domat' and 'Gemlik' cultivars were found to be partially self-fertile, and 'Nizip Yağık' was self-fertile (Korkmaz and Ak 2018).

In 'Eğriburun Nizip' cultivar, the amount of fruit per cluster was determined as 0.007 in selfing and 0.458 in free pollination, and it was determined that more fruit was obtained from free pollination (Gül 2020).

Since the self-productivity of olive varieties differs in different growing areas, the self-fertility status of the olive cultivars 'Gemlik', 'Manzanilla', 'Memecik', 'Nizip Yağlık' and 'Tavsan Yuregi', grown under Antalya conditions, were determined in this study.

2. Materials and Methods

2.1. Materials

The 31-year-old varieties of 'Gemlik', 'Manzanilla', 'Memecik', 'Nizip Yağlık' and 'Tavşan Yüreği', which are located in the Research and Application Land of Akdeniz University Faculty of Agriculture, were used in this experiment. The trees are pruned in a vase shape. During the experiment, cultural processes such as pruning, fertilization and irrigation were applied to the trees in sufficient quantities and at appropriate times. The research site is 3 km from the sea, at 36^0 54 028′ north latitude and 030^0 38 810′ east longitude and its altitude is 38 m. According to a soil analysis made in a commercial firm, the soil structure is clay-loam, the organic matter content (2.69%) is low, and the pH is 8.23.

2.2. Methods

In order to determine the fruit set rates of the varieties, the branches 80 cm above the ground and surrounding the tree 360º were selected and the flowers on the cluster formed on the annual shoots on these branches were counted. In the second week of June, the percentage of fruit set was calculated by determining how many of these flowers had turned into fruit.

2.2.1. Selfing and natural pollination

The research was carried out on trees in the fruiting year (on-year). A few days before the so-called white balloon period for selfing, the flowers on the stems of 3 randomly selected shoots on each tree were counted, enclosed in cloth bags and labeled (Figure 1a). Natural pollination was also applied on the same trees (Figure 1b). In order to increase the rate of selfing, the isolated branches were shaken by hand at regular intervals until the day the sacs emerged. Three shoots were selected randomly from each tree, and flower counts were made on the cluster and labeled (Sütçü 1983; Mete 2009). In both applications, the last counts were made at the end of June, after the fruit set period had passed, the sacs on the isolated branches were removed and the flower counts were carried out. Since the olive flowers are very small, they were counted one by one with a needle tip.

a) Selfing **b**) Natural pollination

Figure 1. Natural pollination and selfing in olives

The self-productivity index (R) formula of cultivars per cluster was calculated according to Moutier (2002) (Table 1).

$$R = \frac{\text{Fruit setting rate obtained from selfing}}{\text{Fruit setting rate obtained from natural pollination}}$$

Table 1. Self-productivity status (R) value categories

Self-efficiency index (R) value category	R
0<0.15	Self-infertile
0.15<0.30	Partially self-fertile
0.30<1.0	Self-fertile

2.2.2. Statistical analysis

The experiment was carried out according to the randomized plot design with 3 replications. Three different trees from each variety were selected, 1 shoot was determined from 3 different directions of each selected tree, and a total of 15 trees from 5 different varieties and 9 shoots for each of 2 different methods were studied. Statistical analysis of the data was made by applying Student's grouping test in JMP (8.0), statistical program and angle transformation was used in the statistical analysis of % values.

3. Results and Discussion

Significant differences in % fruit set rates were determined as a result of self-pollination and natural pollination applications in all cultivars used in the experiment, and the results were found to be statistically significant ($P \leq 0.05$). The percentage of fruit set obtained from natural pollination in all olive cultivars in the experiment was found to be higher than the selfing application. The highest fruit set rates in both natural pollination (5.63%) and selfing (2.30%) were obtained from the 'Tavşan Yüreği' variety (Table 2).

In the 'Gemlik' cultivar, 3.05% fruit set obtained from free pollination was higher than 1.84% fruit set obtained as a result of self-pollination, and this excess was found to be statistically significant ($P \leq 0.05$). Since the obtained R value was 0.60, the variety was determined as self-fertile (Table 2). In accordance with the results, while Gül (2020) found the 'Gemlik' variety productive, some researchers found it partially self-fertile (Çavuşoğlu 1970; Sütçü 1983; Cirik and Gülcan 1988; Kaya and Tekintaş 2006; Mete 2009; Korkmaz and Ak 2018; Gencer 2020). Although the 'Gemlik' variety was found to be self-fertile in the research, due to the high rate of natural pollination, the necessity of using appropriate pollinators was determined.

Table 2. % Fruit set rates and self-productivity indexes determined as a result of natural pollination and selfing in olive varieties in the experiment

Cultivars	Natural pollination	Selfing	R (Self-productivity index)
'Gemlik'	3.05Ba*	1.84Bb	0.60 (Self-fertile)
'Manzanilla'	2.75Ba	0.35Eb	0.12 (Self-infertile)
'Memecik'	3.32Ba	0.97Cb	0.29 (Partially self-fertile)
'Nizip Yağlık'	1.97Ca	0.59Db	0.29 (Partially self-fertile)
'Tavşan Yüreği'	5.63Aa	2.30Ab	0.40 (Self-fertile)

*The difference between applications is significant ($P \leq 0.05$). Capital letters indicate importance according to variants and lower-case letters according to applications.

The fruit set rate (2.75%) obtained as a result of natural pollination in 'Manzanilla' cultivar was considerably higher than that obtained from selfing (0.35%) and the obtained values were found to be statistically significant ($P \leq 0.05$). Since its R value was 0.12, 'Manzanilla' was included in the category of unproductive iself (Table 2). Consistent with the results, Lavee and Datt (1978), Androulakis and Loupassaki (1990), and Cuevas et al. (2009), found the cultivar 'Manzanilla' to be unproductive, while Wu et al. (2002) found it partially unproductive. Also, Tous et al. (1998), stated that the 'Manzanilla' variety gave irregular yields in Spain. As a result of the research, the low fruit set as a result of selfing of the 'Manzanilla' variety showed that suitable pollinators must be kept in the garden in order to increase the yield. For this purpose, Ersoy et al. (1998), determined that suitable pollinators for 'Manzanilla' were 'Uslu' and 'Ayvalık' varieties.

Fruit sets obtained as a result of natural pollination (3.32%) and selfing (0.97%) in 'Memecik' cultivars showed a statistically significant difference ($P \leq 0.05$). 'Memecik' with an R value of 0.29 was determined to be partially self-fertile (Table 2). In accordance with the results, most researchers determined the 'Memecik' variety to be partially self-fertile (Çavuşoğlu 1970; Sütçü 1983; Cirik and Gülcan 1988; Kaya and Tekintaş 2006; Korkmaz and Ak 2018; Mete et al. 2019). However, the fruit set rate obtained from natural pollination was (3.32%), for 'Memecik', which shows that, it is imperative to have suitable pollinators in the garden.

In the 'Nizip Yağlık' cultivar, (1.97%) fruit set was detected in natural pollination and (0.59%) in selfing, and the determined values were statistically significant ($P \leq 0.05$). Since the R value was 0.29, the cultivar was found to be partially self-fertile (Table 2). In accordance with the results obtained, while most researchers found the 'Nizip Yaglik' cultivar to be partially self-fertile (Çavuşoğlu 1970; Sütçü 1983; Cirik and Gülcan 1988; Kaya and Tekintaş 2006; Mete 2009; Mete et al. 2019), on the contrary, Korkmaz and Ak (2018) found the variety to be self-fertile. It revealed the necessity of having suitable pollinators in the garden in order to have a higher free pollination fruit set in the cultivar 'Nizip Yaglik', which had the same R value as 'Memecik'.

The fruit set rate of (5.63%), obtained as the result of natural pollination in 'Rabbit Heart' cultivar, was higher than the (2.30%) set rate obtained from selfing and the value found was statistically significant ($P \leq 0.05$). Since the R value of 'Tavşan Yüreği' is 0.40, the variety is in the self-fertile category (Table 2). Although the 'Tavşan Yüreği' variety is self-fertile, the high rate of free pollination indicates that appropriate pollinator use is necessary in the garden.

4. Conclusions

In the olive cultivars examined in the experiment, the percentage of fruit set obtained from natural pollination was higher than self-pollination. The highest fruit set rates in both natural pollination (5.63%) and selfing (2.30%) were obtained from the 'Tavşan Yüreği' variety. 'Gemlik' and 'Tavşan Yüreği' were determined as self-fertile, 'Memecik' and 'Nizip Yaglik' were partially self-fertile, and 'Manzanilla' was self-inefficient. As a result of natural pollination in some varieties, the % fruit set rate is high, and therefore it has been concluded that suitable pollinators are absolutely necessary for efficient and sustainable production.

In the study, the self-fertility results of the olive cultivars 'Gemlik', 'Manzanilla', 'Memecik', 'Nizip Yağlık' and 'Tavşan Yüreği,' grown in Antalya, showed similarities and differences with the results obtained in other regions. For this reason, it has been determined that it is necessary to investigate the self-productivity status of each variety in the region where it is grown.

Since cross pollination was not implemented during the research, the pollination rates of the cultivars could not be determined. However, this situation should be taken into account in the commercial garden facility and planting should be carried out according to the mutual pollination rates of the varieties.

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Molecular identification of ascochyta blight of *Cicer montbretii* Jaub. & Spach

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ITS

ABSTRACT

Molecular detection of ascochyta blight caused by *Ascochyta rabiei* (Pass.) Labr. is important for effective control of the ascochyta blight and efficient chickpea (*Cicer arietinum* L.) breeding program. The present research was therefore aimed to diagnose ascochyta blight of *C. montbretii* Jaub. & Spach via molecular techniques. Infected plant samples were collected and placed on potato dextrose agar (PDA) medium for 1 week at 20-24℃, and colonies with typical ascochyta blight symptoms were transferred to new PDA medium and incubated for 1 week at 25℃. DNA was isolated from small parts of fungus isolates via the CTAB method. Internal transcribed spacer (ITS) regions (ITS-1, 5.8S rDNA subunit, ITS-2) were amplified with ITS 5 and ITS 4 primers for molecular characterization. Based on the BLAST analysis, the sequence had 99 and 100% nucleotide identity with the corresponding sequence of *A. rabiei* in GeneBank. To our knowledge, this is the first report of ascochyta blight of *C. montbretii* in Turkiye. The pathogen is considered to be co-evolved with *C. montbretii*. Molecular techniques, as in the present study, can be diagnosed with great accuracy, in a short time, and with relatively little effort and expense.

1. Introduction

The genus *Cicer* L. consists of 39 *Cicer* species, including 31 perennials and 8 annuals including cultivated chickpea (*C. arietinum* L.), reported by van der Maesen (1972). From 1972 to 2007, the number of *Cicer* taxa was updated to 44 taxa consisting of 9 annuals and 35 perennials (van der Maesen et al. 2007). The following perennial species, subspecies and varieties were added as new *Cicer* taxa: *C. uludereensis* Donmez (2011), *C. floribundum* Fenzl. var. *amanicola* M. Ozturk & A. Duran, *C. heterophyllum* Contandr., Pamukc. & Quezel var. *kassianum* M. Ozturk & A. Duran and *C. incisum* (Willd.) K. Maly subsp. *serpentinica* M. Ozturk & A. Duran were more recently added (Ozturk et al. 2011, 2013). *C. turcicum* Toker, Berger & Gokturk has been more recently introduced to the scientific world. With new annual *Cicer* species, the number of taxa in the genus has reached 50 taxa, and the most distribution of annual *Cicer* species are found in the Anatolia (Asia minor) region including progenitor, *C. reticulatum* Ladiz. (Toker et al. 2021).

Cicer species have been reported all over the world, from the Canary Islands and the Atlas Mountains, in the west, to South and Central Asia in the east, and from the Ethiopian highlands in the south to the Balkans and Caucasia in the north (van der Maesen 1972, 1987; van der Maesen et al. 2007).

The well-known cultivated species do not only possess high levels of protein and vitamin content in their seeds (Ahlawat et al. 2007; Jukanti et al. 2012), but they can also fix atmospheric nitrogen into soil for the following crop and reduce some diseases, insects and weeds if the plant is used as a rotation crop with small grain cereal-based cropping systems (Kantar et al. 2007). Both cultivated chickpeas, including cream coloured large-seeded chickpeas (*macrosperma* or 'kabuli') and small-seeded chickpeas (*microsperma* or 'desi'), are not only grown for edible dry seeds all over the world, but are also grown for green fresh seeds in some countries including Türkiye. In addition to food usage, dry seeds and hays after harvest have been evaluated for animal feed. In 2020, the total sowing area and production quantity of chickpeas was recorded as 14.8 million ha and 15.1 million tons, respectively. According to the harvested area in the world, chickpeas are known to be the first ranked among cool season food legumes (FAOSTAT 2023). The yield of chickpeas suffers from a/biotic stresses including diseases, insect pests, weeds, heat, cold, drought and salinity as well (Singh and Saxena 1993; Muehlbauer and Kaiser 1994). Among biotic stresses, diseases of chickpea are considered to be the most important biotic stresses (Singh et al. 2007).

Ascochyta (Mycosphaerella) blight is caused by *Ascochyta rabiei* (Pass.) Labr., teleomorph, *Didymella rabiei* (Kovacheski) var. Arx (Syn. *Mycosphaerella rabiei* Kovacheski) (Akamatsu et al. 2012). It is one of the most important devastating foliar diseases of chickpeas worldwide (Shahid et al. 2008). At the same time, it has been reported in most of the chickpea-growing fields (Nene et al. 1996; Singh et al. 2007; Pande et al. 2010). Ascochyta blight of chickpea has caused considerable yield losses of up to 100% in susceptible areas, especially in the years when epidemic conditions occur in producing countries (Verma et al. 1981; Singh et al. 1982; Hawtin and Singh 1984; Kaiser and Muehlbauer 1988; Udupa et al. 1998; Chen et al. 2004; Pande et al. 2010). The fungus generally reproduces in cool (15-25 ℃) and humid (>150 mm rainfall) areas (Pande et al. 2010) and needs at least 6-10 h of leaf wetness to infect (Khaliq et al. 2021). Three pathotypes, pathotype I (the least virulent), pathotype II (moderately virulent) and pathotype III (the most virulent) were determined but later the fourth pathotype (high degree of virulent) has already been reported (Turkkan et al. 2008; Nalcaci et al. 2021). It has not only been found in the cultivated chickpea, but also reported in wild species (Frenkel et al. 2010; Kafadar et al. 2019; von Wettberg et al. 2018). Molecular determination of ascochyta blight of chickpea is essential for effective disease control and efficient chickpea resistance breeding programs. The purpose of the present study is the identification of ascochyta blight of *Cicer montbretii* via molecular techniques.

The pathotyping system, which was described by Udupa et al. (1998) and modified by Imtiaz et al. (2011), is logical and it is the most widely used system: pathotype I (least aggressive), pathotype II (aggressive), pathotype III (highly aggressive), and pathotype IV (most aggressive).

2. Materials and Method

2.1. Plant and pathogen

As plant material, perennial wild chickpea (*C. montbretii* Jaub. & Spach) was used in the present study (Figure 1). *C. montbretii* is called 'deli nohut' in Turkish (Guner et al. 2012). Ascochyta blight (Figure 2) was isolated from the surface of infected leaflets and pods of *C. montbretii* and then stored at 4℃ until use.

2.2. Collection sites

Plant samples of *C. montbretii* were collected in Kozak plateau, Bergama, Izmir in 2017 (Figure 1-2). Plant samples and infected plant parts were collected every 100 m and were controlled, respectively.

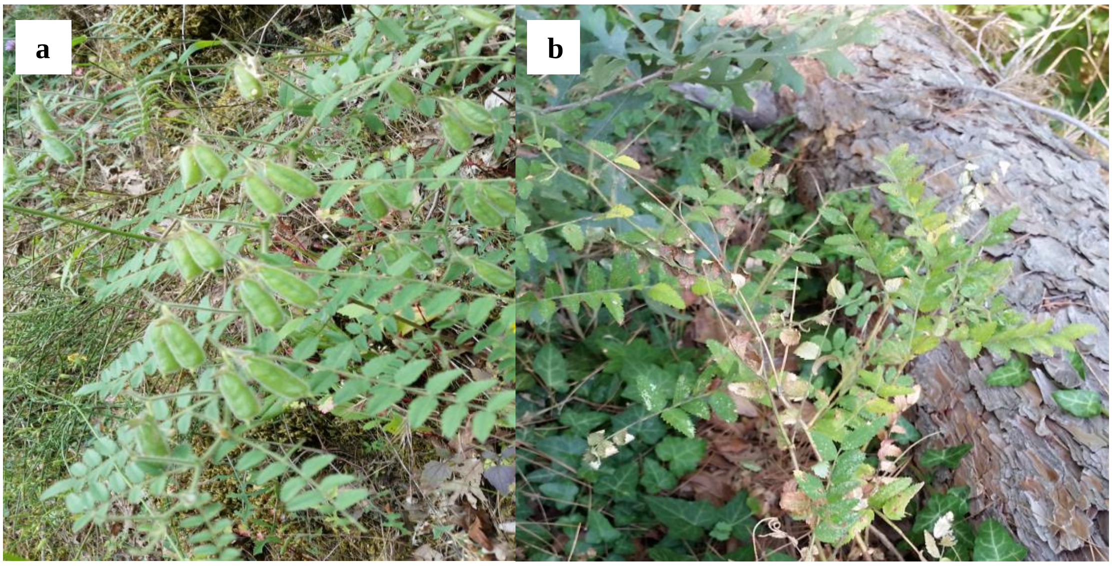

Figure 1. A healthy plant (a) and ascochyta blight infected plant (b) of *C. montbretii* in Kozak plateau road, Bergama, Izmir, Türkiye.

Figure 2. Ascochyta blight on leaf and leaflets of *C. montbretii* in Kozak plateau road, Bergama, Izmir, Türkiye.

2.3. Isolation and reproduction of pathogen

Ascochyta blight fungus was collected from the surface of infected leaflets and pods of *C. montbretii*. Infected and dried plant tissues were applied with 95% ethanol 1 min, sterile distilled water 1 min, 0.5% NaClO 1 min, and sterile distilled water 1 min, and dried on sterile blotting paper respectively (Bahr et al. 2016). With the aid of a scalpel under stereo binocular (Nikon SMZ 460™), only the fungal pathogen was taken from the infected areas. Conidial suspension (1×10^{-6} conidia mL^{-1}) described by Frenkel et al. (2007) was retained on petri dishes consisting of potato dextrose agar (PDA) medium for 1 week at 20-24℃ for 12 h photoperiod under fluorescents lights in order to induce increase in sporulation (Walter 2009). Five isolates for each symptom type were grown as single-spore colonies and used for further studies.

After conidial culture was accomplished, it was placed in PDA medium to obtain single-spore culture. Fungi hyphal fragments were placed on PDA medium to determine single-spore culture and then cultures with single-spore were transferred on cellophane paper to petri medium and then covered with parafilm. These cultures were kept warm for 1 week at 25℃ in an incubator. After the incubation period, colonies including fungi were scraped and transferred to Eppendorf tubes for DNA isolation. Samples including fungal isolates were stored at -20℃ until DNA isolation.

2.4. Pathogen analyses

The total genomic DNA was isolated using fungal spore culture with the CTAB method (Doyle and Doyle 1990). Extracted DNA was manually tested for quality and concentration with 1% agarose gel electrophoresis using a DNA standard. After, the DNA was kept at -20℃ until use. The rDNA internal transcribed spacer (ITS) regions (ITS1, 5.8S rDNA subunit, ITS-2) of ascochyta blight were amplified using PCR with universal primers ITS 5 (forward) and ITS 4 (reverse) in Table 1 (White et al. 1990).

The following PCR procedures were applied: the total reaction mixture volume used was 15 µL containing 8.12 µL Milli-Q water, 1.5 µL 10 × PCR buffer, 1.5 µL $MgCl_2$, 1.5 µL of dNTPs mix, 0.4 µL each primer, 0.08 µL *Taq* DNA polymerase (Fermentas Life Sciences™, Burlington, Canada) and 1.5 µL fungal DNA template (Peever et al. 2007). Amplification was conducted in a thermocycler (Bioneer, MyGenie™) under the following conditions: 94℃ initial denaturation for 5 min, 30 cycles of 94℃ for 30 s, annealing temperature 55℃ for 30 s, 72℃ for 1 min, and then a final extension of 10 min at 72℃ (Barve et al. 2003). The amplified product was visualized under UV light after being dyed with ethidium bromide in 2% agarose gel in 1× TBE buffer. A single band was cleaned with the GeneJET Gel Extraction Kit (Thermo Scientific Ferments™, Vilnius, Lithuania) and sequencing was carried out at Macrogen Inc., Europe via BM Laboratories Ltd., with direct sequencing in both directions using the amplification primers. Sequences of ITS region were compared with the BLAST (Basic Local Alignment Search Tool) sequence analysis tool (http://www.ncbi.nlm.nih.gov/BLAST/) in databases using nucleotide-nucleotide BLAST (blastn) with default settings.

3. Results and Discussion

The purpose of the present study was to identify ascochyta blight of *C. montbretii* Jaub. & Spach via molecular techniques. Previously, molecular characterization studies on ascochyta blight in different chickpea species have been reported in various studies (Phan et al. 2002; Cho et al. 2005; Bahr et al. 2016; Baite et al. 2017; Kumar et al. 2020) including in Türkiye (Bayraktar et al. 2007). However, there were limited studies on the blight in wild *Cicer* species in the world and even in Türkiye (Abbo et al. 2007; Peever et al. 2007; Frenkel et al. 2010; Kafadar et al. 2019; von Wettberg et al. 2018). Also, a first report on ascochyta blight of *C. montbretii* was studied in Bulgaria by Kaiser et al. (1998). A similar approach on ascochyta blight was described for *C. isauricum* P.H. Davis and *C. anatolicum* Alef. (Guler 2018; Tekin et al. 2018). Due to the importance of the ascochyta blight of chickpea, more than 25 QTLs were detected for molecular assisted breeding (Sharma et al. 2012; Misra et al. 2016; Islam et al. 2017). Thanks to some of these QTLs, a chickpea ideotype has been improved as resistant or tolerant to ascochyta blight, heat tolerant, double-podded and about 58 g per 100 seed weight (Eker et al. 2022). In the present study, ascochyta blight isolated from infected leaflets and pods *C. montbretii,* were grown in potato dextrose agar (PDA) medium and developed single spore culture which was put into Eppendorf tubes for molecular characterization. PCR reaction was carried out with ITS5 and ITS4 primers with fungal DNA obtained as a result of DNA isolation. Sequencing of the PCR product was performed. The sequence of the rDNA ITS region of fungal DNA (ITS-1, 5.8S rDNA, ITS-2) with a length of 556 base pairs are presented in Table 2.

Table 1. Primers used in PCR, base sequences and annealing temperatures for diagnosis of ascochyta blight in *C. monbretii* in Kozak plateau road, Bergama, Izmir, Türkiye

No	Primers	Base length	Sequence (5'→3')	Temperature (°C)
1	ITS4	20	TCCTCCGCTTATTGATATGC	58
2	ITS5	22	GGAAGTAAAAGTCGTAACAAGG	63

Table 2. Sequence of the rDNA ITS region of fungal DNA of ascochyta blight in of *C. montbretii* in Kozak plateau, Bergama, Izmir, Türkiye

Line	Sequence of the rDNA ITS region
1	TAACAAGGTT TCCGTAGGTG AACCTGCGGA AGGATCATTA CCTAGAGTTT GTGGGCTTTG
61	CCCGCTACCT CTTACCCATG TCTTTTGAGT ACTTACGTTT CCTCGGCGGG TCCGCCCGCC
121	GATTGGACAA AATCAAACCC TTTGCAGTTG CAATCAGCGT CTGAAAAACA TAATAGTTAC
181	AACTTTCAAC AACGGATCTC TTGGTTCTGG CATCGATGAA GAACGCAGCG AAATGCGATA
241	AGTAGTGTGA ATTGCAGAAT TCAGTGAATC ATCGAATCTT TGAACGCACA TTGCGCCCCT
301	TGGTATTCCA TGGGGCATGC CTGTTCGAGC GTCATTTGTA CCTTCAAGCT TTGCTTGGTG
361	TTGGGTGTTT GTCTCGCCTC TGCGTGTAGA CTCGCCTTAA AACAATTGGC AGCCGGCGTA
421	TTGATTTCGG AGCGCAGTAC ATCTCGCGCT TTGCACTCAT AACGACGACG TCCAAAAGTA
481	CATTTTTACA CTCTTGACCT CGGATCAGGT AGGGATACCC GCTGAACTTA AGCATATCT

The BLAST analysis was performed with the obtained sequence result, having a high degree of similarity with the ITS region (ITS1-5.8S-ITS2) sequences available on the National Center for Biotechnology Information (NCBI) (Figure 3). As a result of the BLAST analysis, the sequence of ITS region was found to overlap 100% with 37 different ascochyta blight isolates. On the other hand, a 99% identity with 34 isolates from all over the world was observed. The ITS sequence studied showed a single nucleotide difference in three different positions with an isolate from East Azerbaijan (MK100148.1) while one cytosine deletion was detected at position 17 compared to the sequence of an isolate from China (KP859584.1).

The importance of using DNA sequences as a primary source of information for species identification of many organisms is increasing day by day (Savolainen et al. 2005; Toker et al. 2021). These sequences are used as species genetic barcodes and are stored in the International Nucleotide Sequence Databases (INSDC) GenBank, EMBL, and DDBJ. Species identifications made in this way have many advantages, such as identifying taxa that are not easy to detect according to morphological diagnosis and preventing false definitions due to phenotypic flexibility.

4. Conclusion

Based on the BLAST analysis, the sequence had 99 and 100% nucleotide identity (Table 2) with the corresponding sequences in GeneBank for *A. rabiei* (Table 3). According to available literature, this is the first report of ascochyta blight of *C. montbretii* in Türkiye. The pathogen is considered to be co-evolved with *C. montbretii*. As is generally known, molecular techniques, as in the present study, can be diagnosed with great accuracy, in a short time, and with relatively little effort and expense. The accurate detection of the disease will provide an insight to chickpea breeders in disease management and improvement of resistant chickpea cultivars.

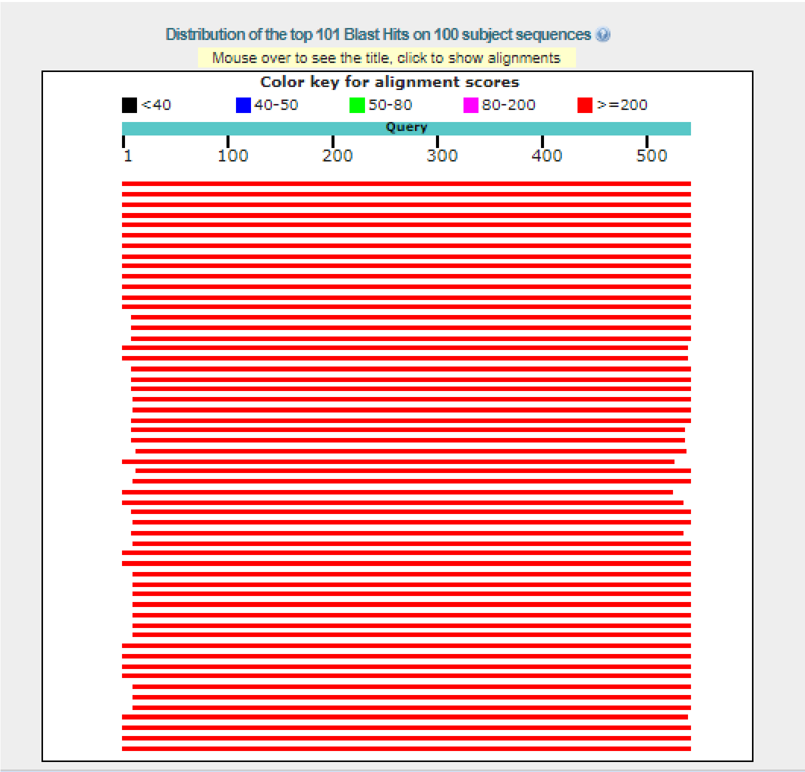

Figure 3. BLAST analyses of ascochyta blight in *C. monbretii* in Kozak plateau, Bergma, Izmir, Türkiye.

Table 3. BLAST analysis of ITS region of ascochyta blight in *C. monbretii* in Kozak plateau road, Bergama, Izmir, Türkiye (NCBI)

Similar sequence region	Similarity (%)
Ascochyta rabiei strain CISA1 small subunit ribosomal RNA gene, partial sequence; internal transcribed spacer 1, 5.8S ribosomal RNA gene, and internal transcribed spacer 2, complete sequence; and large subunit ribosomal RNA gene, partial sequence	100
Didymella rabiei strain CAr03 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, 5.8S ribosomal RNA gene, and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence	100
Ascochyta rabiei strain CBS 237.37 small subunit ribosomal RNA gene, internal transcribed spacer 1, 5.8S ribosomal RNA gene, and internal transcribed spacer 2, complete sequence; and large subunit ribosomal RNA gene, partial sequence	100
Didymella rabiei strain CAr04 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, 5.8S ribosomal RNA gene, and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence	99
Didymella rabiei strain CAr02 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, 5.8S ribosomal RNA gene, and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence	99
Didymella rabiei strain CAr01 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, 5.8S ribosomal RNA gene, and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence	99
Ascochyta rosae culture MFLUCC:15-0063 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, 5.8S ribosomal RNA gene, and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence	99

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Fungi on bean seeds obtained from growers in Isparta province

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ABSTRACT

The fungal load of seeds is among the factors related to seed quality. Seed-borne fungi can cause significant crop losses and may produce mycotoxins, which are harmful to human health. This study aimed to determine the seed-borne fungi of bean, which is among one of the most important crops cultivated in Isparta province. Seed samples from the 2015-2016 vegetation period, obtained from bean growers in Isparta province were used in this study. The fungal load of randomly selected 200 seeds were investigated by blotter and agar methods and prevalence and infestation rates of the fungi were determined. As a result, 41 species of fungi belonging to 26 genera were determined on 62 seed samples. The blotter method yielded 25 genera while 20 genera were determined by the agar method. *Alternaria*, *Aspergillus*, *Cladosporium*, *Fusarium*, *Penicillium* and *Rhizopus* species were the most common fungi found on almost all of the samples, for both methods. Infestation rates of these fungi were also high on bean seeds. Prevalence and infestation rates of the fungi were generally higher in the blotter method, except for *Fusarium* and *Verticillium* species that were determined on the seed samples in higher frequencies by the agar method. *Absidia*, *Arthrinium*, *Epicoccum*, *Nigrospora*, *Scopulariopsis* and *Stachybotrys* species were determined only by the blotter method, while *Seimatosporium* sp. was found by the agar method. *Alternaria*, *Fusarium*, *Rhizoctonia*, *Stemphylium* and *Verticillium* species are known as pathogenic fungi and may cause diseases on bean plants. *Aspergillus* and *Penicillium* species are saprobic fungi producing mycotoxins, so their presence on the seeds is also important.

1. Introduction

Bean (*Phaseolus vulgaris* L.) is a nutritive food that contains high protein and sufficient amounts of carbohydrates and is rich in calcium, potassium, magnesium, and phosphorus as well as various vitamins. Its ability to grow in different regions and to improve soil properties for subsequent agricultural products increases the importance of the bean (Varankaya 2011). Annual average consumption of dry beans per person in Türkiye was 3 kg, indicates its importance in our nutrition (MFAL 2014). Due to its location between the Western Anatolia, Central Anatolia, and Mediterranean Regions, a wide variety of crops can be grown in Isparta province. Field crops are leading with a 49% cultivation rate in the province, and cereals come first among the field crops, followed by legumes (MCT 2016). Chickpeas, lentils, and beans are the most important legumes in terms of cultivation area, production, and yield. In Isparta province in 2021, 1093 tons of dry beans were produced in 7534 decares of land and 19051 tons of green beans and kidney beans were produced on 15822 decares of land (TURKSTAT 2022).

Seeds are among the factors that enable the production of qualified products and yield increase per unit area. Seeds are important not only for their usage as human food, but they also serve as a starting material in plant production. It is of great importance to use high-quality and healthy seeds and production materials to provide the highest yield from the unit area to meet the nutritional needs of the ever-increasing world population. The fact that nearly 90% of agricultural products are grown from seeds highlights the importance of using healthy seeds (Paylan et al. 2011).

The microorganism load of the seed surface is one of the remarkable features that determine the quality of the seed. There are numerous examples in the literature on the spread of plant diseases within and between countries as a result of the import of seeds contaminated with pathogens (Kaiser 1997; Ghangaokar and Kshirsagar 2013; Kurt 2013). In addition, it would be harmful to consume the seeds infested with *Aspergillus*, *Penicillium* and *Fusarium* species as food, since the presence of such fungi indicates the presence of mycotoxins, which are toxic to humans and animals (Tseng et al. 1995a, b; Domijan et al. 2005). Seed-borne pathogens greatly affect seed quality and cause diseases that affect plant production and yield (El-Gali 2015). Seed-borne pathogens have different effects on seeds such as weakening or loss of the germination ability, colour and shape changes, toxin formation and biochemical changes, decrease in yield (between 15-30%), development and spread of plant diseases, inhibition of seed formation or maturation, and seed rot (Baştaş et al. 2004; Zaidi and Pathak 2013).

Various studies have been carried out on fungal diseases of bean seeds throughout the world. *Aspergillus*, *Penicillium*, *Fusarium* and *Botrytis* species are among the common fungal agents carried with the bean seeds, as well as *Alternaria alternata*, *Cladosporium cladosporioides*, *Epicoccum nigrum*, *Rhizoctonia solani*, *Rhizopus stolonifer*, *Stemphylium globuliferum*, *Trichothecium roseum*, *Verticillium dahliae*, *Colletotrichum lindemuthianum*, *Phaeoisariopsis griseola*, *Ascochyta phaseolorum*, *Macrophomina phaseolina*, *Phoma exigua* and *Sclerotinia* sp. (Yesuf and Sangchote 2005; Elwakil et al. 2009).

In Türkiye, there are relatively few studies on the determination of fungi on bean seeds. In a previous study on this subject, 285 bean seed samples obtained from 36 provinces were studied by the blotter method, and 41 fungal species belonging to 32 genera were determined on the seeds (Maden and İren 1984). In another study, conducted in Erzurum province, it was determined that 57 seed samples were infested by *A. alternata*, *Aspergillus* spp., *Botrytis cinerea*, *Cladosporium* spp., *C. lindemuthianum*, *Fusarium acuminatum*, *F. equiseti*, *F. proliferatum*, *F. verticillioides*, *Penicillium* spp., *Phoma glomerata*, *P. medicaginis*, *R. solani*, *R. stolonifer*, *Stemphylium botyosum*, *Trichoderma* spp. *T. roseum* and *Ulocladium atrum* (Demirci and Çağlar 1998) with different rates. As a result of a study conducted in Eskişehir province, 15 fungal species were determined on bean seeds, which were *Cladosporium herbarum*, *C. sporangiosum*, *Penicillium piceum*, *P. camemberti*, *P. frequentans*, *P. rubrum*, *Sclerotinia sclerotiorum*, a steril fungus, *Aspergillus terricola*, *A. carneus*, *Gliocladium roseum*, *Stachybotrys chartarum*, *A. alternata*, *Trichoderma harzianum* and *Phoma* sp. (Küçük et al. 2005).

Bean is one of the crops most widely produced in the agricultural areas of Isparta province. Therefore, the determination of the fungal load of seeds obtained from bean growers in Isparta province was an integral part of this study.

2. Materials and Methods

2.1. Seed Samples

In the study, bean seed samples of different varieties obtained from bean growers in Isparta province in the 2015 and 2016 production seasons were used. According to the sample numbers determined by considering the bean cultivation areas of the districts, 62 seed samples were taken from different villages or locations in the districts (Table 1). Fungi in 200 randomly selected seeds from each seed sample obtained from the producers were determined by the blotter and agar methods (Marcinkowska 2002).

2.2. The blotter method

To determine the superficially transmitted fungal agents on the seeds, 100 seeds were randomly selected from each seed sample. Bean seeds were placed in 9 cm diameter glass Petri dishes with 3 layers of sterile blotter paper moistened with sterile distilled water, with 7 seeds in each dish. Petri dishes were incubated at 22±1°C for 7 days in a climate chamber with a light and dark regimen of 12 hours each.

2.3. The agar method

In the agar method, used to determine the fungal agents carried under the seed coat, 100 seeds were randomly selected from each sample and were subjected to surface disinfection with 1% sodium hypochlorite for 10 minutes, then rinsed with sterile distilled water for 3 minutes to eliminate the superficial microorganisms on the seeds. To prevent bacterial contamination, 7 seeds were placed in sterile 9 cm diameter Petri dishes containing Potato Dextrose Agar (PDA, Biolife-Italy) with 50 mg L^{-1} streptomycin sulfate (Demirci and Çağlar 1998; Küçük et al. 2005) and incubated for 5 days in the climate chamber with similar conditions as in the blotter test.

2.4. Identification of the fungi on the bean seeds

After the incubation period, the seeds were examined under a stereomicroscope and the fungi growing on the seeds were identified and recorded at the genus level. Afterwards, slides prepared with each isolate were examined under the light microscope, and the fungi were identified at the species level by using related literature (Booth 1971; Ellis 1971; 1976; Samson et al. 1995; Watanabe 2002; Leslie and Summerell 2006). Lactofuchsin was used as a dye on the slides (Chamswarng and Cook 1985). The sizes of the sexual or asexual organs or spores of the fungi were measured using an ocular micrometer and compared with the relevant sources. The prevalence and the infestation rates of the fungi in each sample (%) were calculated by the formulas [1] and [2] given below (Duan et al. 2007).

Prevalence rate (%)= (Number of samples with the fungus/Total number of samples) X 100 (1)

Infestation rate (%)= (Number of seeds with fungus/Total number of seeds) X 100 (2)

3. Results and Discussion

As a result of the study, a total of 41 species belonging to 26 different genera were determined on the seed samples (Table 2). Among the fungi isolated from the seed samples, the most common genera were *Alternaria*, *Aspergillus, Cladosporium, Fusarium, Penicillium, Rhizopus* and *Ulocladium.* While some genera such as *Absidia, Arthrinium, Epicoccum, Nigrospora, Scopulariopsis* and *Stachybotrys* were only detected by the blotter method, *Seimatosporium* was only determined in the agar test.

Alternaria alternata, *Aspergillus* spp., *Cladosporium* spp., *Penicillium* spp., *R. stolonifer* and *U. atrum*, commonly found on bean seeds in this study were also previously isolated from bean seeds in Türkiye (Maden and İren 1984; Demirci and Çağlar 1998; Küçük et al. 2005). *Drechslera hawaiiensis, D. spicifera, Epicoccum nigrum, G. roseum, Phoma* spp., *R. solani, Scopulariopsis brevicaulis, S. chartarum, Stemphylium herbarum, Trichoderma* spp., *T. roseum* and *Verticillium* spp., reported to be found on bean seeds in Türkiye by the same authors, were also determined in the present study.

Among the *Fusarium* species found in this study, *F. equiseti*, *F. oxysporum*, *F. sambucinum*, *F. semitectum*, *F. solani* and *F. verticillioides* were previously isolated from bean seeds in Türkiye (Maden and İren 1984; Demirci and Çağlar 1998). *F. avenaceum*, *F. chlamydosporum* and *F. subglutinans* were reported to be found on bean seeds in other countries (Castillo et al. 2004; Marcenaro and Valkonen 2016; Russell et al. 2017). However, there was no record of the isolation of *F. lateritium* and *F. sporotrichoides* from bean seeds, except in the present study. But, *F. lateritium* was reported as one of the most important pathogens which cause root rot on beans in Mexico (Sanchez-Garcia et al. 2006). *F. sporotrichoides* was reported to be isolated from cereals and legumes in Türkiye and considered a weak pathogen (Asan 2017).

Table 1. Bean cultivation areas of the districts of Isparta province (TURKSTAT 2015) and the number of samples taken accordingly

Districts	Dry bean areas (decare)	Green bean areas (decare)	Total area (decare)	Number of Samples
Central District	410	466	876	4
Aksu	579	2300	2879	10
Atabey	141	228	369	2
Eğirdir	265	137	402	2
Gelendost	1350	95	1445	8
Gönen	-	32	32	2
Keçiborlu	82	452	534	4
Senirkent	75	225	300	2
Sütçüler	60	178	238	2
Şarkikaraağaç	9450	480	9930	10
Uluborlu	26	12	38	2
Yalvaç	4 525	810	5 335	10
Yenişarbademli	225	300	525	4
			Total number of samples	**62**

Table 2. The prevalence and infestation rates of fungi determined by blotter and agar tests on bean seed samples produced in Isparta province

Fungus genera	Prevalence rates (%)		Infestation rates (%)	
	Agar test	Blotter test	Agar test	Blotter test
Absidia	0	1.612	0	0.016
Acremonium	3.225	4.838	0.080	0.048
Alternaria	50	79.032	2.483	9.693
Arthrinium	0	3.225	0	0.064
Aspergillus	64.516	100	3.661	27.096
Chaetomium	4.838	11.290	0.096	0.129
Cladosporium	29.032	87.096	1.403	21.096
Doratomyces	3.225	4.838	0.032	0.064
Drechslera	3.225	6.451	0.032	0.096
Epicoccum	0	4.838	0	0.064
Eurotium	6.451	53.225	0.709	3.741
Fusarium	56.451	27.419	1.709	0.596
Gliocladium	3.225	3.225	0.032	0.032
Nigrospora	0	3.225	0	0.064
Paecilomyces	1.612	1.612	0.032	0.016
Penicillium	75.806	100	7.806	42.822
Phoma	1.612	1.612	0.016	0.016
Rhizoctonia	4.838	8.064	0.064	0.096
Rhizopus	58.064	100	5.693	32.451
Scopulariopsis	0	1.612	0	0.032
Seimatosporium	1.612	0	0.016	0
Stachybotrys	0	3.225	0	0.032
Stemphylium	4.838	17.741	0.080	0.306
Trichoderma	9.677	22.580	0.935	0.870
Trichothecium	1.612	4.838	0.016	0.080
Ulocladium	9.677	48. 387	0.129	2.064
Verticillium	4.838	3.225	0.048	0.032

Fungi found both in the present study and previously reported from bean seeds were; *Acremonium strictum* (Abdulwehab et al. 2015), *Eurotium* sp. (Tseng et al. 1995b; Mota et al. 2017), *Chaetomium globosum* and *C. spirale* (Watanabe 2002; Russell et al. 2017), *Nigrospora oryzae* (Ghangaokar and Kshirsagar 2013) and *Scopulariopsis brevicaulis* (Russell et al. 2017). No information was found on the presence of these fungi on bean seeds in Türkiye. However, this is probably the first report in the world indicating that *Absidia*, *Arthrinium*, *Doratomyces*, *Paecilomyces* and *Seimatosporium* species were isolated from bean seeds. *Absidia corymbifera* was detected only in a single seed in a sample taken from the Aksu district. *Absidia* species had been recorded on spices, nuts, sunflower seeds, peaches, maize, cereal products, soybeans and peas, but no record of isolation from bean plants has been found (Pitt and Hocking 1997; Anwar et al. 2013). Two species belonging to the genus *Arthrinium*; *A. phaeospermum* and *A. arundinis* were determined in the seed samples examined in the study. In a study conducted in Argentina, *A. phaeospermum* was detected on wheat, millet, and soybean seeds (Broggi et al. 2007). *A. arundinis* was isolated from the roots and hypocotyls of young bean plants in a study conducted in Japan (Sato et al. 2014). InTürkiye, it was isolated from canola seeds (Alpaslan and Özer 2017). *Doratomyces stemonitis* was isolated from the seed samples taken from Aksu and Atabey by the agar test and from Gelendost and Yalvaç districts by the blotter method. It was reported that the fungus caused rot on potatoes, oat, and maize, resulting in economic loss through a reduction in yield (Webster and Weber 2007). In the present study, two different species belonging to the genus *Paecilomyces* were determined on bean seed samples taken from the Şarkikaraağaç district. These were *P. farinosus* and *P. victoriae*. Although *P. farinosus* is primarily known as an entomopathogen (Leena et al. 2003), it was mentioned among the seed-borne fungi that reduce the germination of spruce and pine seeds (Urosevic 1961). *P. victoriae* was previously isolated from acacia seeds (Vijayan 1988). *Seimatosporium monochaetioides* was detected only in one seed sample obtained from Yenişarbademli and this is the first record of its isolation from bean seeds.

4. Conclusion and Recommendations

As a result of the study, which aimed to determine the fungal agents on bean seeds cultivated in Isparta province, a total of 41 species belonging to 26 different genera were determined from 62 seed samples. In the study, species belonging to *Alternaria*, *Aspergillus*, *Cladosporium*, *Eurotium*, *Fusarium*, *Penicillium*, *Rhizopus* and *Ulocladium* genera were determined to be the most common fungi on bean seed samples. The contamination rates of these fungi were generally parallel to their prevalence rates. Among the fungal genera determined, the highest number of species was determined in the *Fusarium* genus with 11 species. According to our findings, that the prevalence and infestation rates of the fungi determined by the blotter method were higher compared to the agar test, it can be mentioned that superficially transmitted fungi were more common on bean seeds. Important plant pathogens, as well as saprobic fungi, were determined on the seed samples taken from bean growers in Isparta province. *Fusarium solani*, *F. oxysporum*, and *R. solani* are among the pathogenic fungi that negatively affect the growth and yield of beans. Their presence on seeds will increase the prevalence and severity of the diseases they cause, by increasing the pathogen inoculum from year to year. In this respect, it is important to prevent their transmission with seed applications. Especially *Aspergillus*, *Penicillium*, *Cladosporium* and *Stachybotrys* species, which are among the saprobic agents, are known as fungi that synthesize toxic metabolites for humans. Their presence on the seeds consumed as food is harmful. In this respect, it would be appropriate to take measures to prevent the development of these fungi, especially on seeds which are to be used as food.

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Investigation of antimicrobial activities of some sideritis species

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antimicrobial activity

ABSTRACT

This research has been conducted on tea grown in the western Mediterranean region and also on the consumption of *Sideritis stricta* and *Sideritis condensate* species, in order to investigate their antimicrobial activity against 6 pathogenic bacteria. The plants were collected and dried at room temperature in the flowering stage. The essential oil of the plants was obtained with a Clevenger apparatus by the hydrodistillation method. Antibacterial activities of the extracts were determined with the disc diffusion method. In this method, MIC of the extracts which showed antibacterial activity were determined with the microdilution method. *Staphylococcus aureus* ATCC 29213, *Escherichia coli* ATCC 25922, *Enterococcus faecalis* ATCC 29212, *Pseudomonas aeruginosa* ATCC 27853, *Salmonella enteretidis* RSK 95046, *Klebsiella pneumoniae* ATCC 700613 were used as test bacteria. The results were evaluated according to the Clinical and Laboratory Standards Institute (CLSI) criteria. Ampicillin and penicillin were used as the positive control antibiotics. It was determined that hot water extracts of both plants did not have antibacterial activity. The results of the statistical analysis showed that there was a significant difference ($P<0.05$) between the antimicrobial activities of the essential oil of *Sideritis stricta* and *Sideritis condensate*. It was found that there was no significant difference between the antimicrobial activity of *Sideritis stricta* and ampicillin used as a control antibiotic. On the other hand, the antimicrobial activity of *Sideritis condensata* was lower when compared to the control antibiotic.

1. Introduction

Plants have always been the nutriments and the first medicines of people up to the present day. Humans discovered whether plants were poisonous or curative by using them in different ways. Thus, they succeeded in obtaining their active ingredients. Plants have been used for treatment for thousands of years (Çopuroğlu 2013).

It is estimated that there are approximately 750000-1000000 plant species in the world. However, it's been claimed that only 500000 of them have been identified (Baytop 1999). According to the ''Flora of Türkiye and East Aegean Islands'', there are 1251 genus and more than 12000 species and subspecies belonging to 174 families in Türkiye. This means that Türkiye's flora is substantial (Davis et al. 1988; Güner et al. 2000). 234 of these taxons have foreign origins and cultivated plants. The rest of them are plants naturally found in this region (Ekim et al. 1989).

The history of medicinal plants is as old as the history of humanity. Sumerians and Assyrians in B.C 5000-3000 were using medicinal plant, with as many as. 250 different plants being utilized. Greeks, Egyptians, and Hittites were also using medicinal plants. According to the data of the World Health Organization (WHO), there are about 20000 medicinal plants in the world. Since some of them are only being used locally, they cannot be listed completely. In recent years, there is a growing interest in using natural treatment methods; this has brought medicinal plants back onto the agenda. Today, approximately 70% of medicinal plants are being gathered from the natural environment and the rest of them are being cultivated (Baytop 1999).

In recent years, there has been a growth in the number of treatments with medicinal plants, and they are being used for many different types of illnesses (Sağlıkoğlu 2004). Consequently, the number of studies on medicinal plants has also increased.

It is known that, the extract obtained via different methods and volatile oils of aromatic and medicinal plants have some antimicrobial effects (Dorman and Deans 2000). If a plant is rich in alkaloids, volatile oils, glycosides, flavonoids, phenols, coloring agents, tannins and resins named as secondary compounds, it takes place in the group of aromatic and medicinal plants (Baydar 2005). The volatile oils or extracts of these plants have antimicrobial effects (Akgül 1993; Dorman and Deans 2000; Rauha at al. 2000; Marino et al. 2011; Proestos 2006). These antimicrobial effects arise from volatile oils and phenolic compounds with 150-600 IU molecular weight. The compounds, such as basic phenols, phenolic acids, quinones, flavonoids, tannins, coumarins, alkaloids, glycosides, lectins, polypeptides, volatile oils and terpenoids have biological activity and are found in plants. It was determined by some research that these compounds were effective on some pathogenic bacteria such as

Staphylococcus aureus, E. coli, Enterococcus faecalis, (E.faecalis) Pseudomonas aeruginosa, Salmonella enteretidis, Klebsiella pneumoniae (Uğur et al. 2005; Kılıç 2006).

Today medicinal and aromatic plants, which have some positive influences have gained more importance. It is thought that the *Sideritis* species, consumed as a kind of tea, can be used as an antimicrobial. In this study, the antimicrobial formatting of *Sideritis stricta* (*S. stricta)* and *Sideritis condensate* (*S. condensate)*'s extracts and volatile oils were analyzed comparatively. The antimicrobial characteristics of these two species were identified and evaluated statistically.

2. Material and Methods

S. stricta and *S. condensata* species grow in the West Mediterranean Region and are also consumed as tea. In this research, the antimicrobial activities of these species against some pathogenic bacteria were analyzed. Plants were gathered from the Bey mountains, Antalya and kept under room temperatures until analysis. For this analysis, *Staphylococcus aureus* ATCC 29213, *E. coli* ATCC 25922, *E. faecalis* ATCC 29212, *Pseudomonas aeruginosa* ATCC 27853, *Salmonella enteretidis* RSK 95046, *Klebsiella pneumoniae* ATCC 700613 were taken from the Microbiology Laboratory of Akdeniz University Hospital, Antalya.

Volatile oils of *S. stricta* and *S. condensata* were obtained via the hydrodistillation method with a Clevenger apparatus. While obtaining volatile oils, 20 grams of each plant were weighed separately and 300 ml of pure water was added. Then, it was distilled in the Clevenger apparatus for 5 hours until 0.5% yield was achieved (TSI 1991).

In order to obtain hot water extracts of *S. stricta* and *S. condensata*, 0.5 g of each plant was mixed with 100 ml of pure water and shaken. In water bath extracts were obtained in 5 min, 15 min, 25 min at 80°C and 150 rpm rotation. Each extract was filtered by Whatman No:42 filter papers. After this, they were kept under 4°C until further analysis (Zhu at al. 2004).

For antibacterial activity the agar well diffusion and disc diffusion methods were utilized. The bacteria for the disc diffusion method were incubated in a nutrient liquid medium at 37°C for 24 hours. The density of each bacteria, which were revitalized, in sterile physiological serum was adjusted for 0.5 Mc Farland (1x10^8 cfu ml^{-1}). Sterile swabs were submerged into the prepared suspensions. By pressing to the wall of the tube, excess liquid from the top was removed. Muller Hilton Agar (MHA, Merck 103872) filled pre-prepared Petri dishes were inoculated by the streak plate technique and left for 2 hours at 4°C. The Petri dishes were left for incubation for 24 hours at 37°C. In this study, ampicillin, penicillin discs were used for positive control. At the end of the incubation, the diameters of the zones were measured by caliper and evaluated (Ezoubeiri et al. 2005; Uğur et al. 2005).

After inoculation to MHA with the streak plate method, wells with 8mm diameter were dug and 50 µl volume extracts were transferred into the wells. The Petri dishes were left for incubation at 37°C for 24 hours (Ezoubeiri et al. 2005; Uğur et al. 2005).

Minimum inhibition concentrations were determined via the Broth microdilution method for the quantitative determination of antimicrobial activities of all the extracts and volatile oils showing inhibition effect on microorganisms. For this analysis 96 well microplates were used. Except for the first well, all other wells were filled with 50 µl Muller Hinton Broth (MHB, Merck 110293). The first and second well of the first row were filled with 50 µl plant extracts, which has a final density of 128 µg ml^{-1}. Starting from the second well, double dilution occurred by transferring 50 µl volume from well to well. The last well medium was chosen as the control well; therefore, from well before the last well 50 µl volume was removed outside and the last well was left empty. The standard antibiotic was diluted to the second raw wells in the same way. As mentioned above, bacteria suspensions which were adjusted Mc Farland 0.5 were added in 50 µl volume except the last well. Population growth was evaluated due to blur of the wells. The last well without blur was determined as value. Ampicillin, and penicillin antibiotics were used for positive control. Results were evaluated according to zone diameters (Andrews 2001; Bilgehan 2002; Toroğlu and Çenet 2006).

Analyses were carried out with 2 parallels and 2 repetitions. Results were evaluated with variance analysis and different mean values were evaluated with Duncan's multiple range test (Düzgündeş et al. 1987).

3. Results and Discussion

The analysis of variance results in Table 1 display the antimicrobial activities of volatile oils which were obtained from *S. stricta* and *S. condensata*.

The results of Duncan's multiple range test for antimicrobial effects of volatile oils from *S. stricta* and *S. condensata* are given in Table 2.

It was detected that there is a significant difference between the antimicrobial effects of these two species. Results show that the antimicrobial effect of *S. stricta* is not significantly different from the control antibiotic's average effect but *S. condensata* has a lower effect than the control antibiotic.

Karanika et al. (2001) determined that extracts of *Sideritis montana, Origanum dictamnus, Mentha piperita, Rosmarinus officinalis* and *Origanum marjorana* species, which belong to the *Lamiaceae* family, were effective on *Yarrowia lipolytica* yeast. It was believed that the difference between this research was due to the microorganism and plant species.

Uğur et al. (2005), and Kılıç (2006) have conducted similar research. Their results demonstrate that volatile oils of both plants are effective on the growth of all microorganisms. In comparison with other research, it has been thought that the differences originated from the use of different plant species and compounds. In addition, regional and seasonal differences were relevant in this situation (Toroğlu and Çenet 2006).

Table 1. Variance analysis results of antimicrobial effects of volatile oils obtained from two different *Sideritis* species and ampicillin

Variation Sources	S.D.	K.O.	F
Antimicrobial Effect	2	85.18586	66.28**

**Significant at P<0.01 level.

Table 2. Duncan's multiple range test results of antimicrobial effects of volatile oils obtained from *S. stricta* and *S. condensata* plants (mm)

Antimibrobial Effect	N	Diameter of zone (mm)
S. condensata	4	$14.52^a \pm 0.55$
Ampicillin	4	$22.78^b \pm 0.23$
S.stricta	4	$22.23^b \pm 0.78$

The difference between values that have different letters and at the same column (P<0.05).

MIC values of *S. sitricta* and *S. condensata* on *E. faecalis* bacteria were determined by the microdilution method and result MIC value of plant was found 4 µg ml^{-1}. For positive control, penicillin and ampicillin were used (Table 3).

In this study, the antimicrobial effects of *S. sitricta* ve *S. condensata* species on 6 pathogenic bacteria *(Staphylococcus aureus* ATCC 29213*, E. coli* ATCC 25922*, E. faecalis* ATCC 29212*, Pseudomonas aeruginosa* ATCC 27853*, Salmonella enteretidis* RSK 95046*, Klebsiella pneumoniae* ATCC 700613) were found.

Results show that, volatile oils are effective on *E. faecalis* ATCC 29212. Hot water extracts of plants did not have any antimicrobial effect on the test bacteria (Table 4).

According to the findings, plant species are very effective in terms of antimicrobial effects *(P*<0.01). It was observed that the antimicrobial activities of the examined bacteria *S. stricta* and *S. condensata* are significantly different (*(P*<0.05). *S. condensata* species has a lower antimicrobial effect than the control antibiotic's antimicrobial activity. It was determined that *S. stricta*'s antimicrobial effect was not different from the control antibiotic.

Table 3. Results of *S.sitricta's* MIC analysis on *E. faecalis*

E. faecalis	**MIC Values (µg ml^{-1})**											
	128	64	32	16	8	4	2	1	0.5	0.13	0.06	0.03
S.stricta	-	-	-	-	-	-	+	+	+	+	+	+
Ampicillin	-	-	-	-	-	-	+	+	+	+	+	+
Penicillin	-	-	-	-	-	-	+	+	+	+	+	+

Table 4. Results of *S.condensata's* MIC analysis on *E. faecalis*

E. faecalis	**MIC Values (µg ml^{-1})**											
	128	64	32	16	8	4	2	1	0.5	0.13	0.06	0.03
S.condensata	-	-	-	-	-	-	+	+	+	+	+	+
Ampicillin	-	-	-	-	-	-	+	+	+	+	+	+
Penicillin	-	-	-	-	-	-	+	+	+	+	+	+

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Marketing efficiency analysis of beef cattle markets: A case study from the Republic of Benin

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ABSTRACT

This research aimed to assess the efficiency of beef cattle markets in the Republic of Benin. Primary data were collected from face-to-face surveys of a random sample of 600 respondents consisting of 300 beef cattle farmers and 300 beef cattle traders participating in self-managed beef cattle markets (MBA) and traditional beef cattle markets (MT). Different marketing channels were identified in the selected beef cattle markets: Channel I, Farmer-Slaughterhouse/Butchery; Channel II, Farmer-Collector-Wholesaler-Slaughterhouse/Butchery; Channel III, Farmer-Collector-Slaughterhouse/Butchery; and Channel IV, Farmer-Wholesaler-Slaughterhouse/Butchery. Channel I appears to be the most efficient in both markets with a marketing efficiency of 2.57 in MBA markets and 1.23 in MT markets. The average marketing efficiencies are 1.25 and 0.97 in MBA and MT markets, respectively. The marketing efficiency analysis showed that MBA markets are more efficient than MT markets. To increase the marketing efficiency of farmers, MT markets should be converted into MBA markets. Facilitating transportation and access to market information are critical factors for increasing farmers' marketing efficiency.

1. Introduction

The livestock sub-sector occupies an important place in the economy of Benin. Its contribution to GDP is 5.82%, and its share in the Gross Agricultural Production value is 15.55% (FAO and ECOWAS 2016). Particularly the *Peulh* socio-ethnic groups whose main activity is livestock farming traditionally practice livestock farming in both sedentary and nomadic forms. The nomadic livestock system is implemented in many West African countries, and, despite its extensive and low-productive nature, it plays several roles in pastoral regions, which include securing, capitalization, diversification, economic integration, and social integration (Sounon et al. 2019). Livestock represents major marketable assets held by most rural people, and it is also a voracious form of capital (Turner and Williams 2002).

As institutions that facilitate the conversion of livestock into cash, livestock markets play an economic role in Africa (Turner and Williams 2002). Livestock markets vary significantly in their importance and their attractiveness for livestock traders and farmers (Turner and Williams 2002), but in recent years, they have become centres of interest for decision-makers and important pillars of rural development (Onibon 2004). Many African municipalities owe their economic development to livestock markets (SNV 2016). Given the economic role that livestock markets play in rural areas and their contribution to rural development, it is important to conduct scientific investigations to ensure their sustainable development.

Improving livestock marketing systems requires knowledge of their efficiency and how they function. Marketing efficiency provides information on the performance of the marketing system (Kohls and Uhl 1985). Assessing the efficiency of livestock markets will both help identify the most efficient markets to advise stakeholders in and also identify the least efficient to be improved.

This study aimed to assess the efficiency of beef cattle markets in the Republic of Benin. This research is important because it provides information on beef cattle marketing channels, marketing costs, the farmer’s share in the marketing channels, marketing margins, and the marketing efficiency of beef cattle markets in the area studied. This information will help not only the beef cattle market stakeholders to make rational decisions but also national and international institutions to invest in the beef cattle market to improve the marketing system in the Republic of Benin.

To conduct this research, two types of beef cattle markets were studied in the Republic of Benin, traditional markets (MT) and self-managed markets (MBA). Most of the transactions in these markets are for live beef cattle. MT and MBA markets are the two main types of beef cattle markets in the Republic of Benin (Hadj and Aboubakar 2007). In order to reach the goal of this study, the following hypothesis was formulated:

H: Farmers' marketing efficiency is higher in MBA than in MT markets.

MBA markets offer farmers the opportunity to be in direct contact with buyers. This shortens the marketing channel and reduces transaction costs while in the MT, the farmers are more at the mercy of the traders and intermediaries, which creates a long marketing channel and increases transaction costs. The difference in transaction costs between the two types of beef cattle markets explains the difference in their marketing efficiency. Farmers in the MBA markets have a higher transaction efficiency than those in the MT because they incur comparatively fewer costs in transactions and also sell their animals at better prices. The difference in marketing costs and prices could make the farmers' marketing efficiency higher in MBA markets than in MT markets.

2. Materials and Methods

2.1. Sampling and data collection

A two-stage sampling procedure was used to draw the sample respondents. In the first stage, potential beef cattle markets were identified in six municipalities: Gogounou, Nikki, Bassila, Matéri, Savè, and Iwoyé (Kétou), with the help of the head of the Ministry of Agriculture Department. In the second stage, from the beef cattle markets identified, a face-to-face survey was conducted using a structured questionnaire with a random sample of 600 respondents consisting of 300 (150 in MBA and 150 in MT) beef cattle farmers and 300 (150 in MBA and 150 in MT) beef cattle traders. The data was collected in 2017 and considered the last 12 months of production.

In these markets, beef cattle are sold live without being weighed. The prices are fixed by "eye-ball" pricing on a per-head basis and agreements between seller and buyer. This negotiation pricing system is common to many beef cattle markets in African countries (Kocho et al. 2011; Pratama and Supranianondo 2017; Abdullahi et al. 2018). Marketing margins and costs were calculated per head of live animal (Adefemi 2014; Pratama and Supranianondo 2017; Sikamwaya and Guiyu 2020; Lusk et al. 2021; Yusuf et al. 2021). The local currency in the Republic of Benin is the CFA franc, but the currency used in this document is the American dollar ($ US). The data of the World Bank were used in the conversion of the domestic currency to the US dollar (World Bank 2021).

2.2. Measuring marketing efficiency

In general, marketing efficiency refers to the ratio of input and output, and an increase in this ratio represents improved efficiency and vice versa (Kohls and Uhl 1985; Adanacıoğlu 2014). Many methods have been used to measure marketing efficiency; one common method is to examine marketing margins (Rupindo 2009). The profit-to-cost ratio has also been used to determine the efficiency of a marketing system by comparing the marketing benefits gained to marketing costs incurred by the marketing agency (Adefemi 2014). In this context, the market is efficient if the ratio is positive and equally distributed across all marketing institutions. Another method used to determine marketing efficiency is Acharya's modified method andGangwar et al. (2010) used this method to determine the marketing efficiency of broilers in Delhi in India. Adanacıoğlu (2014) also used the same method to determine the efficiency of direct and indirect marketing channels used by farmers of İzmir in Türkiye. Meshack (2015) estimated the marketing efficiency of the beef cattle value chain in the Longido and Monduli districts in Tanzania with Acharya's modified method. Erdoğan et al. (2016) identified the marketing efficiency of apple production in the Senirkent district of the Isparta province in Türkiye using the same method.

Acharya's modified marketing efficiency formula was also used in this study to determine the marketing efficiency of the beef cattle marketing channels in MBA and MT markets in the Republic of Benin. Acharya's modified marketing efficiency formula is used as follows:

MME = NPF / (MC + NMM) (Gangwar et al. 2007; Dastagiri et al. 2012; Adanacıoğlu 2014; Erdoğan et al. 2016).

Where, MME equals modified marketing efficiency, NPF equals net price received by farmers, NPF equals the gross price received by farmers – farmers' marketing cost, MC equals the total marketing cost incurred by farmers and intermediaries, and NMM equals the total net marketing margin earned by the intermediaries.

The marketing cost was calculated by summing up the different costs engaged during the marketing process by a market participant. The marketing margin was calculated by subtracting the sum of the purchase price and the marketing cost from the selling price per head of live animal by a market participant.

Longwe et al. (2010) states that the marketing effectiveness index coefficient should be greater than 1. The larger this coefficient is than 1, the higher the efficiency in the marketing channel. If this coefficient is less than 1 then this indicates that the marketing channel used was not effective.

3. Results and Discussion

3.1. Animal numbers in Benin

In Benin, cattle, sheep and goat assets have gradually increased over the last 17 years. In 2016, the cattle herd increased by 51.82% with 2339 thousand heads, the sheep herd increased by 37.11% with 915 thousand heads and the goat herd increased by 48.04% with 1836 thousand heads. It appears that the number of cattle has experienced more growth than that of sheep and goats. This can be explained by the spread of MBAs in the country, the sedentarisation of some pastoralists and new livestock entrepreneurs (Table 1). Despite the large number of animals, there is unsatisfied demand for meat in general.

In 2016, cattle meat production increased by 53.11% with a total production of 40 thousand metric tons, sheep meat production increased by 36.21% with a total production of 9 thousand metric tons and goat meat production increased by 48.04% with a total production of 9151 metric tons. Cattle and goat meat cover a large portion of the red meat production (Table 2).

3.2. Beef cattle marketing channels used by farmers

Table 3 shows that almost half of the farmers (148) sold directly to butchers (Channel I) while the others sold to butchers through collectors and wholesalers. Channel I is the most widely used while Channel II is the least used by producers. 49.3% of producers use Channel I while 10% use Channel II.

3.3. Marketing costs and margins in alternative beef cattle marketing channels

Table 4 and Table 5 show the marketing costs per head of beef cattle in MBA and MT markets. In MBA markets, the total marketing costs for each channel were 48.90 $ per head, 66.46 $ per head, 65.08 $ per head, and 58.73 $ per head, for Channel I, Channel II, Channel III, and Channel IV respectively. The average marketing cost in the MBA markets was 59.79 $ per head.

Table 1. The herd of large and small ruminants in Benin (1000 Heads)

Years	Cattle	Index (2000= 100)	Sheep	Index (2000= 100)	Goat	Index (2000= 100)
2000	1541	100.00	667	100.00	1240	100.00
2001	1599	103.76	679	101.76	1266	102.10
2002	1639	106.40	683	102.39	1320	106.40
2003	1676	108.79	690	103.40	1306	105.30
2004	1718	111.51	708	106.09	1346	108.53
2005	1718	111.51	724	108.49	1386	111.75
2006	1810	117.48	742	111.19	1427	115.06
2007	1857	120.53	762	114.23	1454	117.21
2008	1905	123.65	781	116.99	1483	119.60
2009	1954	126.83	791	118.53	1570	126.59
2010	2005	130.14	808	121.08	1605	129.41
2011	2058	133.58	825	123.63	1640	132.23
2012	2111	137.02	842	126.17	1678	135.30
2013	2166	140.59	860	128.87	1716	138.36
2014	2222	144.23	878	131.57	1755	141.51
2015	2280	147.99	896	134.27	1795	144.73
2016	2339	151.82	915	137.11	1836	148.04

Source: FAOSTAT, 2022, FAOSTAT Database, www.fao.org/faostat.

Table 2. Red meat production in Benin (Metric Ton)

Year	Cattle (MT)	Index (2000= 100)	Sheep (MT)	Index (2000= 100)	Goat (MT)	Index (2000= 100)
2000	26126	100.00	6607	100.00	6182	100.00
2001	27108	103.76	6724	101.76	6311	102.10
2002	27797	106.40	6765	102.39	6578	106.40
2003	28421	108.79	6832	103.40	6510	105.30
2004	29131	111.51	7010	106.09	6709	108.53
2005	29131	111.51	7168	108.49	6908	111.75
2006	30693	117.48	7347	111.19	7113	115.06
2007	31490	120.53	7548	114.23	7246	117.21
2008	32304	123.65	7730	116.99	7393	119.60
2009	33135	126.83	7832	118.53	7826	126.59
2010	34000	130.14	8000	121.08	8000	129.41
2011	35000	133.97	8000	121.08	8174	132.23
2012	36000	137.80	9000	136.21	8364	135.30
2013	37000	141.62	9000	136.21	8553	138.36
2014	38000	145.45	9000	136.21	8748	141.51
2015	39000	149.28	9000	136.21	8947	144.73
2016	40000	153.11	9000	136.21	9151	148.04

Source: FAOSTAT, 2022, FAOSTAT Database, www.fao.org/faostat.

Table 3. Beef cattle marketing channels used by the farmers studied

Marketing Channels	Frequency	Percentage
Channel I: Farmer- Slaughterhouse / Butchery	148	49.30
Channel II: Farmer -Collector-Wholesaler- Slaughterhouse / Butchery	30	10.00
Channel III: Farmer -Collector- Slaughterhouse / Butchery	59	19.70
Channel IV: Farmer -Wholesaler- Slaughterhouse / Butchery	63	21.00
Total	300	100.00

Table 4. Marketing costs in MBA ($/head)

Marketing costs	Channel I	Channel II	Channel III	Channel IV	Mean
Transportation	17.64	17.64	17.64	18.94	17.97
Loading and unloading	4.73	4.73	4.73	5.17	4.84
Veterinary control	2.58	2.58	2.58	2.58	2.58
Taxes	4.13	6.03	5.17	5.34	5.17
Commissions	0.00	8.78	8.44	9.82	6.76
Ropes	6.03	7.75	7.75	6.89	7.10
Feed	13.78	18.94	18.77	9.99	15.37
Total marketing cost	48.90	66.46	65.08	58.73	59.79

Table 5. Marketing costs in MT ($/head)

Marketing costs	Channel I	Channel II	Channel III	Channel IV	Mean
Transportation	28.07	28.07	28.07	28.07	28.07
Loading and unloading	4.31	4.31	4.31	4.31	4.31
Veterinary control	2.58	2.58	2.58	2.58	2.58
Taxes	10.16	10.51	10.85	13.61	11.28
Commissions	0.00	26.69	16.36	4.31	11.84
Ropes	12.74	14.64	12.92	10.33	12.66
Feed	11.02	17.05	17.05	11.88	14.25
Total marketing cost	68.89	103.85	92.14	75.09	85.00

In MT markets, the total marketing costs for each channel were 68.89 $ per head, 103.85 $ per head, 92.14 $ per head, and 75.09 $ per head, for Channel I, Channel II, Channel III, and Channel IV respectively. The average marketing cost in the MT market was 85.00 $ per head.

In both markets, Channel I had the lowest cost and Channel II, which was the longest, had the highest cost. Among the costs, transportation was the highest for each channel in both markets. This is due to the poor road infrastructure and inadequate means of transportation (Ajala and Adesehinwa 2007). The average marketing costs in the MT market was higher than in the MBA market. The difference in marketing costs was due to poor marketing infrastructure, lack of market information, poor road conditions and exorbitant transportation costs, lack of good organization, and lack of standardization and classification, especially in MT markets (Ajala and Adesehinwa 2007).

Table 6 and Table 7 show marketing margins and the farmer's share of the beef cattle marketing channels. The farmer's share is the percentage of the price received by the farmer compared to the selling price of the retailer. In both markets, Channel I has the highest farmer's share (77.68% for MBA, 63.14% for MT) and Channel II the lowest farmer's share (50.00% for MBA, 57.71% for MT). The average farmer's share was 61.86% and 59.64% in the MBA and MT beef cattle markets, respectively. The larger the farmer's share, the more efficient the marketing (Pratama and Supranianondo 2017; Zhu et al. 2019).

The average marketing margins were 314.05 $ per head and 265.88 $ per head in the MBA and MT beef cattle markets, respectively. The difference in marketing margins in both markets is due to the difference between the selling and buying prices and the transaction costs incurred by farmers in each market.

The costs incurred in the transaction of animals by farmers in MBA were less than in MT markets. This is due to the reduction of some costs in MBA including commission fees, corruption charges in the markets, etc.

The difference observed in the selling and buying prices in both markets is due to the price fixing mechanism in each market. In MT markets, farmers have little involvement in price formation whereas in MBA markets, the seller and buyer determine the price together. Onibon (2004) stated that the selling price of an animal in the MBA market is about 25% higher than the selling price of the same animal when sold in the MT market.

3.4. *Marketing efficiency of the beef cattle trade in MBA and MT markets*

Table 8 and Table 9 show the marketing efficiency for the beef cattle trade. In both markets, Channel I had the highest marketing efficiency (2.57 for MBA, 1.23 for MT) and Channel II had the lowest marketing efficiency (0.80 for MBA, 0.81 for MT). The average marketing efficiency found for MBA was 1.25 and for MT was 0.97. This showed that, for the beef cattle trade, MBA beef cattle markets were more efficient than MT ones.

In the MBA and MT markets, there are two marketing channels with a marketing efficiency ratio greater than 1. One of these marketing channels is Channel I (farmer–slaughterhouse/butcher) where there are very few intermediaries. The farmer sells directly to the slaughterhouse or butcher. The second marketing channel is Channel IV (farmer–wholesaler–slaughterhouse/butcher). Although Channel IV is not a very short marketing channel, unlike other channels (Channel II and III), it does not include animal collectors who have been identified as a factor in increasing marketing costs and margins. The price difference and marketing costs could explain the difference in marketing efficiency observed in Channel IV and Channels II and III. In order to determine the difference in marketing efficiencies of the marketing channels for beef cattle, it is necessary to know the costs and prices received by the final consumers (Yusuf et al. 2021).

Table 6. Marketing margins and farmers' share in marketing channels in the MBA markets

Particulars	Channel I	Channel II	Channel III	Channel IV	Mean
The price received by the farmers ($/head) (1)	601.99	421.93	444.97	495.99	491.22
The butcher's sale price to the consumer ($/head) (2)	774.98	843.87	792.20	780.15	803.68
Marketing margin ($/head) (2-1)	172.99	421.93	347.23	284.16	314.05
Farmers' share in the consumer price (%) [(1/2) *100]	77.68	50.00	56.17	63.58	61.86

Table 7. Marketing margins and farmers' share in marketing channels in the MT markets

Particulars	Channel I	Channel II	Channel III	Channel IV	Mean
The price received by the farmers ($/head) (1)	378.88	396.88	393.00	395.43	391.05
The butcher's sale price to the consumer ($/head) (2)	600.09	687.67	680.26	659.70	656.93
Marketing margin ($/head) (2-1)	221.21	290.79	287.26	264.27	265.88
Farmers' share in the consumer price (%) [(1/2) *100]	63.14	57.71	57.77	59.94	59.64

Table 8. Marketing efficiency for beef cattle in MBA markets

Particulars	Channel I	Channel II	Channel III	Channel IV	Mean
The price received by the farmers ($/head) (1)	601.99	421.93	444.97	495.99	491.22
Marketing costs incurred by farmers ($/head) (2)	8.61	18.08	18.08	12.06	14.21
Net price received by the farmers ($/head) (1-2)= 3	593.38	403.85	426.88	483.93	477.01
Total Marketing Cost ($/head) (4)	48.90	66.46	65.08	58.73	59.79
The total marketing margin of the market intermediaries ($/head) (5)	181.60	440.02	365.32	296.21	320.79
Marketing Efficiency [3/ (4+5)]	2.57	0.80	0.99	1.36	1.43

Table 9. Marketing efficiency for beef cattle in MT markets

Particulars	Channel I	Channel II	Channel III	Channel IV	Mean
The price received by the farmers ($/head) (1)	378.88	396.88	393.00	395.43	391.05
Marketing costs incurred by farmers ($/head) (2)	9.47	42.54	32.55	18.08	25.66
Net price received by the farmers ($/head) (1-2)= 3	369.41	354.34	360.45	377.35	365.39
Total Marketing Cost ($/head) (4)	68.89	103.85	92.14	75.09	84.99
The total marketing margin of the market intermediaries ($/head) (5)	230.69	333.33	319.81	282.35	291.54
Marketing Efficiency [3/ (4+5)]	1.23	0.81	0.87	1.06	0.99

3.5. General discussion

In most African countries such as Benin, animals are often sold live in livestock markets through different marketing channels involving multiple actors at different levels (Kocho et al. 2011; Abdullahi et al. 2018). In this study, four marketing channels were identified in the beef cattle markets selected. These channels include market participants such as beef cattle farmers, collectors, wholesalers, retailers (slaughterhouse/butcheries). In the beef cattle markets in the area studied, animals are generally traded by "eye-ball" pricing on a per-head basis, and agreements between seller and buyer are reached after negotiations sometimes involving commissioners (brokers) (Kocho et al. 2011; Pratama and Supranianondo 2017; Abdullahi et al. 2018). Animal prices are higher in the MBA markets than in the MT markets (Onibon 2004).

The marketing costs are relatively lower in the MBA market than those in the MT markets (Onibon 2004). Transportation is the highest costs in all channels in both markets due to the poor road infrastructure and the inadequate means of transportation (Dinku et al. 2021). High transportation costs are generally faced by livestock actors in Africa (Meshack 2015; Okeke-Agulu and Ochelle 2019; Sikamwaya and Guiyu 2020). The high marketing costs in the MT markets show their low efficiency. The higher the transaction costs, the more inefficient the market (Meshack 2015; Dinku et al. 2021).

Marketing margin estimates were made on a per head basis (Adefemi 2014; Pratama and Supranianondo 2017; Sikamwaya and Guiyu 2020; Lusk et al. 2021; Yusuf et al. 2021). The marketing margins per head of beef cattle in the MBA beef cattle markets were higher than those in MT beef cattle markets. The farmer's shares in MBA markets were higher than those in MT markets. The larger the farmer's share, the more efficient the marketing system (Pratama and Supranianondo 2017).

Marketing efficiency is the degree of market performance (Giroh et al. 2010). The average marking efficiency in MBA and MT beef cattle markets were 1.25 and 0.97, respectively, for beef cattle trade. Taiye (2018) found 1.00 for marketing efficiency in the beef cattle market of Ibarapa in Nigeria, which implies that the cattle market was efficient. Okeke-Agulu and Ochelle (2019) found 0.89 for beef cattle marketing efficiency in the Jos metropolis in the state of Plateau, Nigeria because marketing costs constitute a very high percentage of sales. The difference in the results may be due to the methodology used to estimate the marketing efficiency, the price difference, or the marketing costs.

4. Conclusion

Based on the results of this research, for beef cattle trade in MBA and MT beef cattle markets, it can be seen that marketing Channel I is the most efficient, showing the lowest value for the marketing margin and the highest value of farmer's share. The results also highlighted the fact that MBA beef cattle markets are more efficient than MT beef cattle markets for beef trade.

To improve the efficiency of beef cattle markets in the studied area, farmers should form groups and associations to improve access to information, increase participation in formal markets (MBA), and reduce transaction costs (Onibon 2004). Promoting MBA markets will reduce intermediaries and make the marketing system efficient because the shorter the channel, the more efficient the trade (Dewi et al. 2021). Local governments should invest in livestock markets and road infrastructure because participation and access to livestock markets are influenced by good road conditions and access to market information.

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Consumers' willingness to pay for organic beans in southwest Nigeria: towards food safety

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ABSTRACT

Minimizing the health dangers associated with consuming inorganic staple food crops due to residues from pesticide and herbicide usage is a reasonable pathway to ensure nutrition security. Therefore, an extensive knowledge of consumers' interest in organic foods would be a useful complementary strategy to public health interventions. This study examines consumers' willingness to pay for organic beans in southwest Nigeria. Primary data were collected from 180 shoppers of beans. The data were analysed with descriptive statistics and a logistic regression model. Consumers were willing to pay for organic beans if the premium was not more than ₦601.76 (USD 1.58) for 2 kg of organic beans. The significant factors influencing the consumers' willingness to pay for organic beans were gender, access to food safety information, acquaintance with organic products, monthly income, and nutritional knowledge of the food planner. Meanwhile, taste/palatability, freshness, appearance, safety, nutritional value, hygiene, and environmental friendliness were highly ranked when buying beans compared to price and convenience. Therefore, any welfare programme involving the introduction of organic beans in Nigeria should ensure that the premium should not be greater than ₦601.76. Also, policies aimed at improving food safety, and nutritional knowledge should be put in place by the government.

1. Introduction

Organic farming contributes significantly to social well-being through healthy community development. Organic farming avoids harm such as water contamination, pandemics associated with conventional agriculture, biodiversity erosion, food scares, and pesticide poisoning, leading to the death of people (Muhammad et al. 2016). Organic agriculture is based on the sustainability of the agroecosystem, involving farming activities that enhance agroecosystem health, soil biological activity, and sustainable biological cycles (James et al. 2019; Phillip and Dipeolu 2010). It does not use herbicides, chemical fertilizers, synthetic pesticides, gene manipulation, antibiotics, or growth hormones; instead, it employs techniques that aid pollution reduction and ecosystem sustainability (Saleki et al. 2019; Oyawole et al. 2016). It supports the environment by avoiding the use of pesticides, inorganic fertilizers, and other chemically related inputs in agricultural production. Continuous use of pesticides and fertilizers results in the deterioration of the environment, soil health and nutrient imbalance (Vats et al. 2012). Organic farming is currently gaining global recognition in terms of the role it plays in providing safe food and income. Although organic farming is characterised by low yield (Dobbs and Smolik 1996; Pham and Shively 2019), the high premium tag makes up for the low yield recorded among farmers (Delate et al. 2003; Delbridge et al. 2011).

Consumers are showing serious concerns about the safety of the food they consume, which influences them to try to source organic food (Alphonce and Waized 2020; Joya et al. 2022; Kumar et al. 2018; Ortega and Tschirley 2017). They have become more concerned about food quality due to pesticide and fertilizer residuals and contamination of conventional agriculture. Consumers buy organic foods due to the perception that it is healthy, safe, and environmentally friendly (Krissof 1998; Güney and Giraldo 2019). For example, older people may want to purchase organic products because they are cautious about what they eat for health reasons (Falola 2014). Globally, policymakers are more concerned about the production and consumption of organic products due to food safety and environmental quality (Owusu and Anifori 2013). The consumption of organic food could help prevent some health problems, such as cancer and allergic diseases, related to the consumption of conventional food (Owusu and Anifori 2013).

One of the most widely consumed legumes by people and livestock is cowpea (*Vigna unguiculata*), commonly called beans in Nigeria. Beans have many nutrients, which leads to high consumption rates, as well as being a major source of protein in Nigeria, as animal sources of protein such as meat and fish are expensive. They are also rich in zinc, phosphorus, potassium, calcium, folate, iron, B-vitamins and fibre, but low in fat content. Human nutrition studies have revealed that eating beans has both nutritional and health benefits (Curran 2012; Sichilima et al. 2016). For example, it can prevent heart disease, lower blood cholesterol and control constipation, colon cancer, and obesity

(Akibode and Maredia 2012). Thus, beans are very crucial to a wide range of consumers, including both poor and rich households, pregnant women, adults, and infants (Sichilima et al. 2016).

However, the production of beans largely depends on the use of insecticides and other chemical inputs. The use of insecticides, pesticides, fertilizers, and herbicides in the production of beans results in health risks and environmental problems that can be averted by the organic production of beans. Recently reported dangers related to consuming conventional beans due to residues from pesticides and herbicide usage have increased the search for organic beans worldwide. Conventionally produced beans sold in the market pose food safety risks to consumers, such as microbial pathogens, fertilizers, and pesticide residues. This makes the larger global population, especially in developed nations, more concerned about their food safety and an increased desire to consume foods free from any chemical substances.

Minimising health dangers related to consuming inorganic staple food crops due to residues from pesticide and herbicide usage is a reasonable pathway to ensure nutrition security. Therefore, an extensive knowledge of consumers' interest in organic foods would be a useful complementary strategy to public health interventions. In order to formulate relevant policies on the consumption of organic beans, there is a need to assess consumers' willingness to pay (WTP) for such beans. However, studies on WTP for organic food has largely been focused on vegetables with no focus on beans (Ajibade et al. 2017; Bhavsar et al. 2018; Güney and Giraldo 2019; James et al. 2019; Narine et al. 2015; Owusu and Anifori 2013; Oyawole et al. 2016; Phillip and Dipeolu 2010; Saleki et al. 2019). The studies showed that consumers are aware of organic vegetables and are willing to pay for them. Furthermore, education, awareness, income and bid price have been reported to influence consumers' willingness to pay for organic vegetables (Adekunle et al. 2016; Ajibade et al. 2017; Owusu et al. 2013; Oyawole et al. 2016). But awareness and willingness to pay for organic beans has received little or no attention in the literature. This creates a gap in WTP for organic food literature.

This study, therefore, aims to assess consumers' WTP for organic beans in southwest Nigeria. Specifically, the study sought to (i) investigate the quality attributes consumers desire in organic beans; (ii) assess the WTP for organic beans; (iii) estimate the premium consumers are willing to pay, and (iv) determine the factors influencing WTP for organic beans by the consumers. Since there is a huge potential in the local organic industry, this research will be of importance to agricultural marketers who may decide to offer organic foods to the domestic market in the future. The outcome would also be useful to relevant stakeholders, such as farmers, food vendors and retailers, to help build consumer confidence in general. Besides, this study could assist policy-makers with agricultural and public health intervention strategies, especially in the pursuit towards achieving food security in terms of quality and nutrition.

2. Materials and Methods

2.1. Study area

The study was conducted in Ogun State, located in southwest Nigeria. The state is primarily agrarian and lies within longitudes 20°45'E and 3°55'E and latitudes 70°1'N and 7°58'N in the tropics, with a landmass of 16,762 km^2. The mainstay of the state is agriculture. The common food crops produced in the state are rice, beans, maize, yam, and cassava. The state has twenty local government areas (LGAs), among which the populace of Abeokuta South and Odeda LGAs are commonly known for the marketing of food crops. Of prominence among the food crop markets are the Eleweran and Kuto markets, which are renowned for the marketing of beans in large quantities in Abeokuta South and Odeda LGAs, respectively.

2.2. Sampling procedure and data collection

The target population of interest for this study was made up of consumers (shoppers) of beans in the study area. This research employed a three-stage sampling procedure. The first stage was a purposive selection of Abeokuta South and Odeda LGAs as being renowned for the marketing of food crops in the state. In the second stage, the two markets renowned for the marketing of beans in the LGAs—Eleweran and Kuto markets—were purposively selected. Then, systematic random sampling technique was used to select respondents in each market at purchase points. Every fourth buyer was sampled and interviewed. The substitution method was used in the case of rejection by a potential respondent. Ninety (90) respondents were chosen from each of the two markets, making a total of 180 respondents, which were used for the study.

Primary data were sourced from the bean buyers through pre-tested questionnaires. Data collected include the respondent's socioeconomic profile, perception and ranking of quality attributes consumers desire in market beans, willingness-to-pay (WTP) for such beans, and amount willing to pay.

2.3. Data analysis

This study employed the contingent valuation method to examine consumers' WTP for organic beans. Bean shoppers were asked if they are willing to pay a price or not. Those willing to pay were further asked to specify the highest amount they were willing to pay for organic beans.

Descriptive statistics such as frequency, percentage, mean, and bar charts were used to explore the socio-economic characteristics of the bean shoppers, the importance of quality attributes to them and the importance of price on consumers' decision to pay for organic beans. It was also used to determine the average amount they would be willing to pay and major constraints to WTP for organic beans by the unwilling shoppers.

The mean WTP was expressed as:

$$MWTP = \frac{I}{n}\sum_{i=1}^{n} y_i$$

Where n= total number of respondents willing to pay, y_i= willingness to pay for consumer i (amount).

The logistic regression model was used to investigate the driving factors of the buyers' WTP for organic beans. This was used because the decision to pay for organic beans was dichotomous and it has been employed in previous studies (Narine et al. 2015; Oyawole et al. 2016; Xu et al. 2018). The explanatory variables in the model were selected based on previous studies on WTP (Falola 2014; Narine et al. 2015; Owusu and Anifori 2013).

The model is explicitly expressed as follows:

$$Y_i = \beta_0 + \beta_1 G + \beta_2 A + \beta_3 E + \beta_4 HS + \beta_5 I + \beta_6 M + \beta_7 OP + \beta_8 FSI + \beta_9 IP + \beta_{10} NK + e_i$$

Where:

Y_i= WTP for organic beans (yes= 1, no= 0)

G= Gender of the buyer (female= 1, male= 0)

A= Age of the buyer (years)

E= Educational attainment (years of successful schooling)

HS= Household size

I= Average monthly income (amount in naira)

M= Membership of social organization (member= 1, not a member= 0)

OP= Acquaintance with organic products (yes= 1, no= 0)

FSI= Access to food safety information (yes= 1, no= 0)

IP= Importance attached to price (very important= 4, fairly important= 3, less important= 2 and not important= 1)

NK= Nutritional knowledge of food planner (very high= 4, high= 3, low= 2, very low= 1)

β_0= Constant

β_{1-10}= Coefficient

e_i= Error term

3. Results and Discussion

3.1. Socio-economic characteristics of the beans shoppers

Table 1 presents the socio-economic profile of the bean shoppers. Most of the respondents were females. This seems to suggest that more females shop for beans than males. The shoppers were, on average, 39 years, showing they are middle-aged where they might have knowledge about food safety (Falola et al. 2022). The majority of the shoppers had one form of formal education or another. A high level of formal education could enable them to have in depth knowledge about organic food and its health benefits. The larger proportion (58.3%) of the respondents were married, while 26.1% were single. Others were either widowed or divorced. About two-thirds of the shoppers had household sizes ranging from one to five people, while about one-third had between six and ten people in their households. Further analysis revealed that the mean household size of the respondents was about five people. The majority of the shoppers were members of social organizations, which could influence their willingness to pay, as cooperative societies disseminate useful information to their members (Mukaila et al. 2022). The majority of the bean shoppers were acquainted with organic

Table 1. Socioeconomic characteristics of the beans shoppers

Variable	Category	Frequency	Percentage
Gender	Male	54	30.0
	Female	126	70.0
Age (years)	≤ 30	69	38.3
	31-40	46	25.6
	41-50	35	19.4
	51-60	25	13.9
	> 60	5	2.8
Educational level	No education	12	6.7
	Primary	8	4.4
	Secondary	17	9.5
	Tertiary	143	79.4
Marital status	Single	47	26.1
	Married	105	58.3
	Divorced	5	2.8
	Widowed	19	10.6
	Separated	4	2.2
Household size	1-5	113	62.8
	6-10	67	37.2
Occupation	Studentship	21	11.7
	Artisanship	72	40.0
	Trading	39	21.6
	Civil service	48	26.7
Employment status	Student	22	12.2
	Full-time employed	89	49.4
	Part-time employed	6	3.3
	Self-employed	57	31.7
	Retired	6	3.3
Social organization	Yes	158	87.8
	No	22	12.2
Acquainted with organic product	Yes	154	85.6
	No	26	14.4
Food safety information	Yes	138	76.7
	No	42	23.3
Monthly income (₦)	≤ 30000	29	16.1
	30000-40000	48	26.7
	40000-50000	54	30
	50000-60000	21	11.6
	≥60000	28	15.6

products and had knowledge about food safety. The finding that consumers, who have access to information on food safety, are more concerned about the quality of beans they consume reveals the importance of providing credible information on food safety to consumers. The distribution of the respondents according to their monthly income shows that the majority of the shoppers earned more than ₦30000 (USD 78.62), which is the minimum monthly salary in the Nigerian civil service.

3.2. Importance of quality attributes to the beans shoppers

Figure 1 shows the ranking of the importance attached to organic beans bought from markets by the shoppers. From Figure 1, it can be deduced that taste and palatability, freshness and good appearance, safety and health, nutritional value, hygiene, and environmental friendliness are highly ranked when buying in markets compared to price and convenience. Investigations during the survey revealed that the majority of consumers use different kinds of signs to indicate food safety during the purchase. Their concern about food safety can influence their willingness to pay for organic food as it is safer than conventional foods produced using chemical inputs. According to Bhavsar et al. (2018), consumers are changing their food consumption patterns due to concerns about their health and food's nutritional value. These results indicate that consumers are aware of the desirable qualities and nutritional value of healthy food products.

3.3. Willingness-to-pay for organic beans by the beans shoppers

This section examines the level of WTP for organic beans by the shoppers. Table 2 shows the consumers' WTP, the amount they were willing to pay and how much more they are willing to pay. It is worthy of note that the bags of beans sold in the various market segments vary in weight and size; however, they use a common measuring pan for the consumers. In most of the markets, a full measuring pan weighing 2 kg of beans (Ife brown-IT-288) sells at ₦450 (USD 1.18). Meanwhile, consumers were willing to pay ₦601.76 (USD 1.58) on average for the same measure (2 kg) of organic beans. The majority (87.6%) of the shoppers were willing to pay for organic beans in the markets. Further analysis of the results revealed that the mean WTP for a 2 kg bag of beans was ₦601.76 (USD 1.58) for the organic beans. The analysis also revealed that 57.1% of the willing shoppers could pay more than the mean WTP. However, only 1.3% of the willing shoppers were willing to pay above ₦1000 (USD 2.62).

Table 2. Consumers' willingness to pay and amount willing to pay

Variables	Category	Frequency	Percentage
Willingness-to-pay	Yes	156	87.6
	No	24	12.4
Amount willing-to-pay (₦)	500-700	113	72.4
	800-1000	41	26.3
	> 1000	2	1.3

3.4. Major constraints to WTP for organic beans by the unwilling shoppers

Table 3 shows the results of the investigations made to understand why some (13.3%) of the shoppers were not willing to pay for organic beans, if available. The major constraint limiting the unwilling shoppers from buying organic beans in the study area was authenticity The shoppers argued that organic foods were credence goods. In other words, they stated that they could not differentiate between organic beans and conventional ones. This was reported by 37.5% of the unwilling respondents, representing 5% of all the shoppers interviewed. Another reason given by the non-willing consumers in the study area was the long distance to purchase points, as given by 33.3% of the unwilling shoppers. Twenty-nine per cent of the unwilling shoppers complained that organic products were usually expensive and that if organic beans were introduced in the study area, they would be difficult to afford.

Table 3. Major constraints to WTP for organic beans by the unwilling shoppers (n= 24)

Factors	Frequency	Percentage
Authenticity	9	37.5
Long-distance to purchase point	8	33.3
High price	7	29.2
Total	24	100

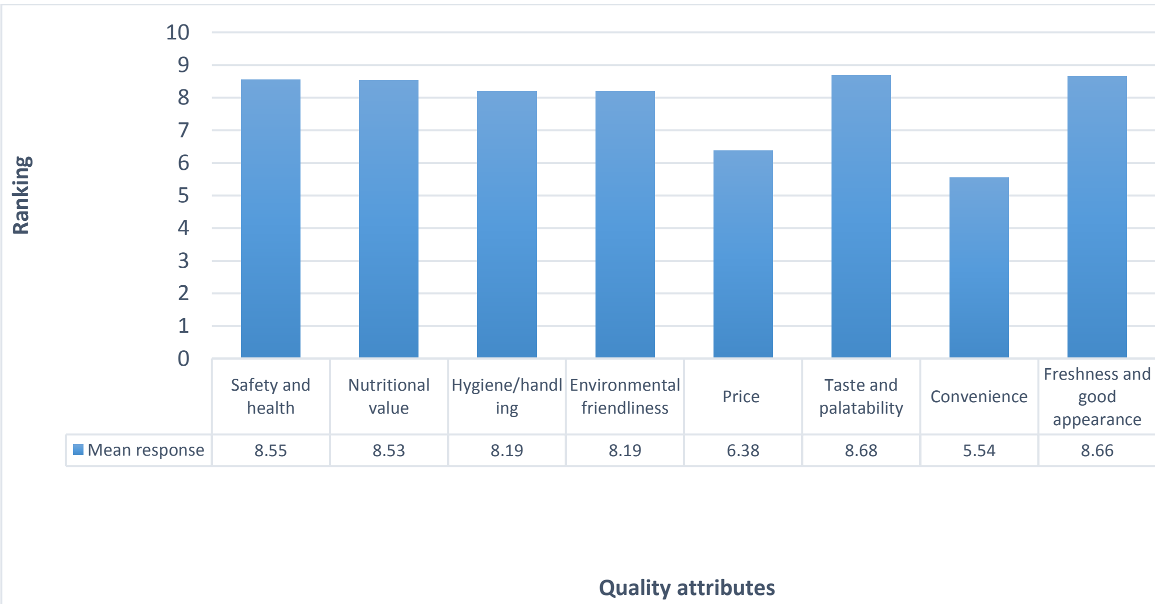

Figure 1. Ranking of desirable attributes of beans.

3.5. Importance of price on consumer's decision to pay for organic beans

The importance attached to price could have an important influence on consumers' interest in organic food. Table 4 shows the distribution of the buyers according to the importance they attached to price in their decision. In evaluating the shoppers' decisions according to price factors, a large proportion (60%) of the consumers did not consider price to be an important factor in their decision to pay for organic beans. They reported that health benefits and food safety mattered to them more than price. Just 5% considered that price was very important in their decision to pay for organic beans. This finding indicates that consumers are becoming more conscious of the health-related dangers associated with the consumption of inorganic foods than the prices of organic ones. This supports Alphonce and Waized (2020), Joya et al. (2022), Kumar et al. (2018), and Ortega and Tschirley (2017), that consumers are concerned about the health implications of the food they eat.

Table 4. Importance of price on consumer's decision to pay for organic beans

Variables	Frequency	Percentage
Very important	9	5.0
Fairly important	20	11.1
Less important	43	23.9
Not important	108	60.0
Total	180	100

3.6. Determinants of consumers' willingness to pay for organic beans

Table 5 presents the results of the logistic regression employed to investigate the factors influencing buyers' WTP for organic beans. The chi-square of 149.91 (with $P<0.0000$) obtained in this study indicates that the variables included in the model were significant. The likelihood function of the model was negative and close to zero (-16.76916); all of these suggest that the model has a good fit. The results in the table show that six of the ten hypothesized independent variables influenced the probability of paying for organic beans by consumers. The independent variables that influenced the respondents' WTP for organic beans were gender, age, monthly income, acquaintance with organic products, access to food safety information, and nutritional knowledge of the food planner.

The coefficient of the respondents' gender is positive and significant. This probably means that being of the female gender increases the probability of WTP for organic beans. This could be because women are more knowledgeable about food safety and are in charge of food and nutrition in the household, especially in developing countries. This supports the findings of Narine et al. (2015), that being a female enhances WTP for organic food.

The age of the shoppers positively influenced their WTP for organic beans. This suggests that older shoppers are willing to pay for organic beans. This is in tandem with the findings of Falola (2014), who reported that older people are willing to pay for organic food. Older people are more concerned about their safety, probably due to the reduction in their immune system as they advance in age (Falola 2014).

Average monthly income was also significant and directly influenced WTP for organic beans in the study area. All things being equal, buyers with higher incomes are more likely to have a greater capacity to pay a higher price for safe foods than their counterparts. Adekunle et al. (2016) and Narine et al. (2015) reported a similar finding that consumers' WTP for organic food increases parallel to income.

Also, acquaintance with organic products had a positive effect on consumers' WTP for organic beans. The result implies that respondents who are acquainted with organic products were willing to pay for organic beans in the markets. Consumers that are acquainted with organic products would know the importance and benefits related to consuming organic food products.

Access to food safety information also had a positive relationship with WTP for organic beans. This implies that an individual that has access to food safety information and is concerned about their safety in terms of food consumption is likely to pay for organic beans. This could be because such consumers are likely to be aware of the health hazards related to unwholesome conventional foods. This conforms with the findings of Owusu and Anifori (2013) who reported that concern about food safety and awareness influenced the consumers' WTP for organic food.

Table 5. Determinants of willingness to pay for organic beans by the respondents

Variables	Coeff	Std. error	t-value	p-value
Gender	0.3428**	0.1678	2.04	0.043
Age	0.0253*	0.0134	1.89	0.057
Educational level attained	0.0130	0.0219	0.59	0.554
Household size	-0.0704	0.0987	-0.71	0.476
Monthly income	3.95e06**	1.69e-06	2.34	0.020
Membership in social organization	-0.1697	0.2004	-0.85	0.398
Acquaintance with organic products	1.4772***	0.2129	6.94	0.000
Access to food safety information	0.9365***	0.3225	2.90	0.004
The importance attached to the price	-0.0884	0.0765	-1.16	0.249
Nutritional knowledge of food planner	0.0276**	0.0139	1.99	0.048
Constant	-2.4986	1.0282	-2.09	0.038
Chi^2 (10)= 149.91				
Prob>chi2= 0.0000				
Log-likelihood= -16.76916				
Pseudo R^2= 0.817				

*** ($P<0.01$), ** ($P<0.05$) and * ($P<0.1$)

Nutritional knowledge of the food planner of a household also positively and significantly influences WTP for organic beans in the markets. The result suggests that households whose food planners have a high level of nutritional knowledge will be more willing to buy organic beans because of their nutritional value than those whose food planners have a low level of knowledge. The knowledge of the health benefits of organic foods influenced consumers' WTP (Narine et al. 2015).

4. Conclusions

Minimising health dangers related to consuming inorganic food crops due to residues from chemical fertilizers, pesticides, and herbicide usage is a reasonable pathway to ensure food safety. Therefore, understanding consumers' interest in organic foods would be a useful complementary strategy to public health interventions. This study examined the willingness of consumers to pay for organic beans in southwest Nigeria. From the findings, it can be concluded that the bean shoppers were aware of the potential nutritional safety of organic products, and the majority of the consumers would be willing to pay for organic beans if available. Thus, organic food products are safe for consumption and their production would improve consumers' health. The study further revealed that gender, age, monthly income, acquaintance with organic products, access to information on food safety and nutritional knowledge of food planners were the major factors affecting consumers' WTP for organic beans. This study also showed that taste and palatability, freshness and good appearance, safety and health, nutritional value, hygiene, and environmental friendliness are highly ranked when buying beans in the markets compared to price and convenience. The major constraint to WTP for organic beans was the authenticity of the produce.

From the findings, it is recommended that any food safety and welfare programme involving sales of organic beans in the Nigerian markets, especially in the study area, should ensure that the premium should not be greater than ₦601.76 (USD 1.58). A designated special shopping mall or market where only organic foods are sold would help to curb the problem of distinguishing organic products from conventional foods. It is also recommended that policies aimed at improving households' access to food safety information and nutritional knowledge of the household's food planner should be put in place by the government and other relevant nutrition security agencies. This may involve educating people on food safety through enlightenment programmes. Besides, people should be informed about the importance of, and create awareness about, organic products. In the same vein, universities and other training institutes could also include food safety and nutrition security in their programmes.

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Farm households' input demand and output supply response to price shocks in Nigeria

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ABSTRACT

Panel data on farm household output for a full range of commodities are scarce, and as a consequence, only a few other studies have considered estimating farm household output supply and input demand response to price changes in Nigeria using panel data within the multiple inputs and multiple outputs frameworks. This study examined the extent to which farm households' respond to production inputs and output price changes using panel data covering the period 2010-2016. Specifically, to determine whether a commodity output's price positively affects its supply and other output categories; and whether an input price negatively affects its usage in Nigeria within the multiple input and multiple output (MI-MO) framework. The translog profit function was used to simultaneously examine the production response of farm households' in terms of the factor demand and produce supply. Seven output supply and four input demand equations were estimated. The results indicated that the response of output supply to own price ranged from 0.59 for animal products and 1.24 for cereals. The own-price demand elasticities of farm input range from -0.82 for mechanisation to -1.46 for intermediate inputs. Also, a substantial degree of farm households' response to input price shocks. Farm inputs and outputs were economic complements to price changes. Therefore, price policy issues aimed at improving the production response of farm households' to both input and output price shocks should be developed with a particular focus on farm inputs.

1. Introduction

Despite the reforms in Sub-Saharan Africa (SSA), agricultural policy in the last decades, reduced productivity has been linked to a weak supply response among other factors to market signals (Di Marcantonio et al 2014). The notion that the supply response of farmers' to price changes is generally very low and/or absent has not been widely accepted as studies have shown that smallholders respond to price signals. However, this argument has attracted controversy in policymaking (Haile et al. 2015).

Response to agricultural production is associated with the change in agricultural output due to commodity price changes (Mythili 2008), and in Nigeria, this is policy-induced (Obayelu and Salau 2010). Nigerian major commodity farm producers have been directly hit by the burden of commodity prices, so when prices increase they earn more profits, but suffer losses and absorb shocks when there is a price fall. Consequently, food commodities have become unstable in both prices and demand and this discourages production, thus making outputs and possible export potentials suffer (Mesike et al. 2010).

In the last two decades, smallholder farmers have been subjected to shocks in output and input prices in Nigeria of which the implications on their welfare have been much debated. Molitor et al. (2017) posited that to be more resilient against price shocks, smallholder farmers need to diversify their cropping practices. However, this behavioural response can only be successful if they can respond to input prices as well as technological change.

Price and change in technology are important tools for improving agricultural productivity. The availability of appropriate technology should be followed by a positive price policy to stimulate agricultural production through the desired level of input allocation. To achieve desired growth in agricultural output, policymakers are faced with the challenges of formulating agricultural policy, as there is a close link between output supply and input demand (Kumar et al. 2010). Hence, understanding how farm households' respond to output and input price signals constitutes crucial information for policymakers in achieving farm productivity. Even if subsistence farming is not considered an important driver of economic growth, it has still a major influence on the welfare of the farming population (Poulton et al. 2006). Moreover, understanding the relationship between input and output prices, food supply, and input demand could improve the market participation of smallholders (Barrett 2008). The agricultural supply response measurement is useful, not only to policy stakeholders but to other decision-makers such as farmers and production marketing chain actors. The degree of farmers' responsiveness to price shocks provides a rich

This study was conceptualized, conducted and reported in accordance with the Research Ethics Policy of the Federal University of Agriculture Abeokuta, Nigeria.

understanding of agricultural sector roles in the economy, particularly domestic responsiveness to price shocks.

Most agricultural systems of production are characterized by multiple inputs and outputs, despite this fact, most agricultural production systems' econometric models have used a single equation production function. This approach is based on a single output, such as wheat, or aggregates all outputs into an output index. It is important to note that, agricultural production decisions on output depend on decisions about other outputs. Therefore, examining only one output leads to specification error as this does not take into account the multiple-output nature of agricultural production. Besides, in a situation of aggregate output index, vital information on the relationships between various output categories is lost. In either case, the estimated parameters validity of such supply response elasticities is called into question.

The well-functioning of farm input markets is a crucial condition for the competitiveness and growth of rural development, particularly in the agricultural sector. Besides, the functioning of the input markets themselves is influenced by changes in agriculture input price, output price, and the rural economy. Despite the Nigerian government's efforts at restoring the country's agricultural sector to its pride through policy and programs, there has been a failure to significantly get rid of the constraints affecting the development of the agricultural system of which input and output prices are important. This is partly due to the lack of empirical work on agricultural supply response in Nigeria. Motivated by this concern, this study attempts to overcome some of these problems in the case of output supply response estimates for the Nigerian food staples to input and output price shocks. This study aims to estimate a system of input demand and output supply responses for Nigerian agriculture using a multi-input and multi-output profit function framework.

The theoretical framework is grounded on the premise of supply response in agrarian production. Supply response generally refers to the variation in agricultural output production and acreage substantially as a result of price changes (Olayide and Heady 1982). This implies that the supply response concept refers to shifts, and the movements along the supply curve mainly due to the price-output quantity relationship can be only isolated in theory, ceteris paribus. Supply response entails the agricultural production output response to product price change. This may be due to the use of more or fewer inputs that may be a result of the price variation. Again, the supply response may be induced by a variation in farm size. Also, the changes in technology under the influence of product variables such as price, credit, rainfall, market information, and so on, may bring out both output supply, and input demand response. Hence, supply response has to do with the drivers of the movement of the output supply curve (Akanni and Okeowo 2011).

Supply response estimation of food crops, such as the input use changes, has been reported in several studies (Battese et al 1998; Dawson and Lingard 1989). But, few studies have reported the supply response of input demand to changes in price. Profit function analysis is an approach to describe the system of input demand and output supply response to changes in price (Olwande et al. 2009). Numerous studies on agrarian commodity economics have framed their analyses within the single commodity (multi-input, single-output) framework. Within this single commodity framework, it's implicitly or explicitly assumed that allocation of inputs is separable and independent of output allocation decisions. The challenge of a single commodity framework seems to be inappropriate as many agricultural production systems are characterized by multi-product farms as food crops cultivated in both dry and wet land areas are practically in the form of mixed cropping and/or inter-cropping. Based on this diversification type, farmers make decisions on planting several crops and the allocation of the required input simultaneously. Under this framework, production decisions about an output are very likely to be related to the production decisions concerning other outputs.

The production technology describes all feasible options available for the transformation of inputs into outputs. In the Multiple Inputs-Multiple Outputs (MI-MO) framework, the production technology may be described by way of a production transformation set. The boundary of a production transformation set can be represented in equation (1) as follows:

$$f(X, Y, Z) = 0 \qquad (1)$$

Where:

$Y= Y_1, Y_2..., Y_m$ is a vector of m non-negative outputs,

$X= X_{m+1}, X_{m+2}..., X_n$ is a vector of (n-m) non-negative variable inputs, and

$Z= Z_{n+1}, Z_{n+2}, ..., Z_p$ is a vector of (p-n) non-negative quasi-fixed inputs.

Equation (1) is the implicit form of Y= fX; Z, That is, Y-fX; Z= fY, X, Z= 0. The variable inputs are inputs that are full changes to their profit-maximizing levels within one sample period. Quasi-fixed inputs, on the other hand, are inputs that do not necessarily change fully within one sample period.

It is obvious that the production transformation set, F, is determined principally by the technological knowledge state, and physical laws such as climate. For instance, the process of production of crop outputs is limited by agronomical, and other technical aspects. It is also affected by non-technical aspects such as government regulations, e.g. pollution control in the form of pesticide usage restriction and government intervention in output price support.

It is worth noting that a production transformation set possesses certain regularity properties, such as (i) Domain, (ii) Continuity, (iii) Boundedness, (iv) Smoothness and Twice Differentiability, (v) Convexity, and (vi) Monotonicity, of which details can be found in Siregar (1991). Among these regularity properties, convexity and monotonicity are often assumed to hold for the production transformation set. The reason is that the economic behavior implied by profit maximization would always be consistent with these properties being true for the production transformation set.

In the primal approach of profit maximization, a set of output supply equations and input demand equations can be obtained, by estimating equation (1). However, there are at least three major disadvantages to this approach. First, the production function direct estimation using ordinary least squares (OLS) leads to the simultaneity bias as input levels are endogenous. As well, OLS estimation of the output supply equations is inefficient as the error terms are most likely correlated contemporaneously. The same thing also applies to OLS estimation of the input demand equations. Second, if equation (1) is used to examine production decisions, the output supply, and input demand equation derivation is much more complex as it involves solving a constrained profit maximization (Wall and Fisher 1987). Third, the profit function involves only the prices of outputs and inputs and the quantity of quasi-fixed inputs, which are not endogenous, unlike the production function.

The dual approach is not subjected to these disadvantages. Assuming that a producer aims to maximize variable profits and that a production technology set can be represented by equation (1), the profit maximization problem in the dual approach can be expressed as follows:

$$\prod(\mathrm{P},\mathrm{W},\mathrm{Z}) = \max((P'Y - W'X; F(Y,X;Z) \leq 0)) \qquad (2)$$

Where:
P= P_1, P_2, …, P_m is a vector of output prices,
R= R_{m+1}, R_{m+2}, …, R_n is a vector of variable input prices, and the inequality < allows for a case of output inefficiency.

Where P is a vector of Y output prices, W is a vector of X input prices, Y is a vector of P output quantities, x is vector of R input quantities. Other definitions of $\prod(\mathrm{P},\mathrm{R},\mathrm{Z})$ to be used here are:

$$\prod(\mathrm{P},\mathrm{W},\mathrm{Z}) = \max((P'Y - C(W'Y)) \qquad (2a),$$

and

$$\prod(\mathrm{P},\mathrm{W},\mathrm{Z}) = \max(R(P,X) - W'X)) \qquad (2b)$$

Where:
$C(W'Y)$ is the firm's cost function and $R(P,X)$ is the firm's revenue function (Diewert 1974).

As is well known, the vector of Hicksian or constant output demand functions, μ(W, Y), is obtained from C(W, Y) by simple differentiation with respect to W. Similarly, the vector of compensated (i.e., constant input) output supply functions V(P, X) is derived from R(P, X) by differentiation with respect to P. Finally, the Marshallian vectors of output supply and input demands Y(P, W) and X(P, W), respectively] are obtained from $\prod(\mathrm{P},\mathrm{W})$ by differentiation with respect to P and W, respectively.

The derivatives of the Hicksian demand function with respect to input prices, $\frac{\delta \mu_i}{\delta w_j} = \frac{\delta^2 C}{\delta w_i \delta_{w_j}}$ reflect movements along an isoquant for given output levels. Similarly, the derivatives of the compensated output function $\frac{\delta V_K}{\delta P_g} = \frac{\delta^2 R}{\delta P_K \delta_{P_g}}$, reflect movements along the production possibility frontier, i.e., at constant input levels. Thus, to measure compensated factor demand and output supply elasticities using only knowledge of the profit function estimates, the second derivatives of the cost and revenue functions must be expressed in terms of the profit function in equations (3) and (4).

As with equation (1), equation (2) also has certain regularity properties. It is shown by McFadden (1978) that if properties (i) and (iii) are adhered to in the production technology set, then 'Π' is a convex, positively linearly homogenous, closed, and continuous function in both variable input and output prices for every positive fixed input (property vii). Furthermore, if production technology set (F) holds properties (i), (ii), and (iii), then, as shown by McFadden (1978), 'Π' will be continuous jointly for all variables input and output prices and for all fixed inputs (property viii). Another property of 'Π' is that it is monotonic in prices (property ix). Alternatives to equation (2) are revenue maximization and cost minimization. Since profit is revenue minus cost, it is obvious that revenue maximization and cost minimization are special cases of profit maximization. Given its more general nature, profit maximization is preferable to the other two.

Duality means that if both the production function (F) and profit function (Π) fulfill certain regularity properties, the production function or the profit function can be applied to equally well describe the production technology. Duality proofs can be found for instance in Jorgenson and Lau (1974) and McFadden (1978). McFadden (1978) shows the duality between production transformation sets and profit functions using the mathematical theory of convex conjugate functions. As was mentioned, a production technology set satisfying properties (i) and (iii) will result in a profit function satisfying property (vii). McFadden (1978) shows that a profit function holding property (vii) will yield a production transformation set satisfying properties (i), (iii), (v), and (vi). It follows that the profit function as well as the output supply and input demand functions, which may be derived from the profit function, can be treated as if they come from a production technology that satisfies the properties of monotonicity and convexity even if these properties do not hold for the production technology. The output supply and input demand functions can be obtained by taking the profit function's first derivative using Hotelling's lemma as follows:

$$\frac{d\prod(P,R,Z)}{dP_i} = Y_i(P,R,Z) \quad (3) \qquad \text{for } i = 1,2,3\ldots\ldots\ldots, m,$$

and

$$\frac{-d\prod(P,R,Z)}{dR_j} = X_j(P,R,Z) \quad (4) \qquad \text{for } j = m+1, m+2, \ldots, n,$$

Where:
$Y_i(P,R,Z)$ is output supply equations, and $X_j(P,R,Z)$ is input demand equations. Since, from (1), X, Y, and Z are positive, (3) and (4) indicate that profit is expected to monotonically increase with output prices and quasi-inputs, and monotonically decrease with input prices, respectively. Assuming profit maximization, without assuming convexity and monotonicity of production function, fundamental propositions of neo-classical profit maximization behavior can be elaborated as in the following equations:

$$\frac{dY_i(P,R,Z)}{dP_i} = \frac{d}{dP_i}\left(\frac{d\prod(P,R,Z)}{dP_i}\right) = \frac{d^2\prod(P,R,Z)}{dP_i^2} \qquad (5)$$

Since Π is a convex function, then $\frac{dY_i(P,R,Z)}{dP_i}$ which is the slope of supply functions, is positive. Furthermore:

$$\frac{dY_i(P,R,Z)}{dR_j} = \frac{d}{dR_j}\left(\frac{-d\prod(P,R,Z)}{dR_j}\right) = \frac{-d^2\prod(P,R,Z)}{dR_j^2} \quad (6)$$

Since Π is a convex function, then $\frac{dY_i(P,R,Z)}{dR_j}$, which is the slope of input functions, is negative.

Another important proposition of the output supply and input demand functions is the symmetry in cross-price effects.

$$\frac{dY_i(P,R,Z)}{dP_j} = \frac{d}{dP_j}\left(\frac{d\prod(P,R,Z)}{dP_i}\right) = \frac{d}{dP_i}\left(\frac{d\prod(P,R,Z)}{dP_j}\right) = \frac{dY_j(P,R,Z)}{dP_i} \qquad (7)$$

$$\frac{dX_j(P,R,Z)}{dR_i} = \frac{d}{dR_i}\left(\frac{d\prod(P,R,Z)}{dR_j}\right) = \frac{d}{dR_j}\left(\frac{d\prod(P,R,Z)}{dR_i}\right) = \frac{dX_i(P,R,Z)}{dR_j} \qquad (8)$$

There are several characteristics of a production technology that are useful for modeling a production technology. The characteristics are (a) homogeneity, (b) homotheticity, (c) separability and homothetic separability, and (d) non-jointness. Hasenkamp (1976) and Weaver (1983) show that the production function is uniformly homogenous of degree c (where c≠1) in outputs if and only if the profit function is homogenous of degree 1/(1-c) in output prices and fixed factors. Similarly, the production function is homogenous of degree 'c' in variable input if and only if the profit function is homogenous of degree 1/(1-c) in output prices and the profit function is homogenous of degree – c/(1-c) in variable input prices. If a continuously differentiable function is homogenous with degree c, then its first derivative is homogenous with degree c/c-1 in variable input prices.

Production technology is almost homothetic if it can be expressed as follows:

$$F[H(Y,X;Z)],X;Z) \qquad (9)$$

Where F is monotonic in H, and H is homogenous of degree one in Y. It is apparent from (9) that every homogenous function is homothetic but a homothetic function is not necessarily homogenous.

Separability characteristic forms the basis of aggregating data. Partitioning outputs and inputs into three subsets: N_1= (Y_1, Y_2, …, Y_m), N_2= (X_{m+1}, X_{m+2}, …, X_n), and N_3= (Z_{n+1}, Z_{m+2}, …, Z_p), production technology is weakly separable if it can be written as follows:

$$F[a_1(N_1), a_2(N_2); a_3(N_3)] = 0 \qquad (10)$$

Where a_1 , a_2 , and a_3 are aggregator functions. Weak separability is a necessary condition, but not a sufficient condition for consistent aggregation. Both conditions are satisfied by the characteristic of weak homothetic separability. However, if the production function is assumed to be homogenous of degree one, as is usually done, the conditions for weak separability and weak homothetic separability are the same (Wall and Fisher 1987). A function is weak homothetic separable in $N_i$if it is both homothetic and weakly separable in N_i. In terms of the profit function, given that the duality properties hold, Weaver (1977) and Lau (1978) show that production function is homothetically separable in a group of commodities (outputs or inputs) if and only if the profit function is homothetically separable in that commodity's prices.

Lau (1978), defines a production function to be non-joint in inputs and/or in outputs if single production functions exist. Ball (1988), states that when an output is produced by a production technology that is joint in input quantities, decisions about its production depend on choices made about other outputs, e.g. the level of each output produced is dependent upon the prices of competing outputs. So a production function can be represented by a set of independent functions as follows:

$$F_i(Y_i, X_{ij}; Z_{ik}) = 0 \qquad (11)$$

Where X_{ij}= amount of variable input X_j allocated to output Y_i, and Z_{ik}= amount of quasi input.

Z_k allocated to output Y_i. Non-jointness is not of much interest in agriculture because the use of multiple inputs is virtually the rule (Wall and Fisher 1987).

Concerning elasticities, Lau (1972) shows that substitution elasticity is not sufficient as a description of a production technology. In addition, substitution elasticity does not have a straightforward interpretation in the case of MI-MO, whereas the price elasticity does. Following Weaver (1983) and Wall and Fisher (1987), the price elasticities of output supply and input demand, respectively, are:

$$E_{ih} = \frac{dY_i}{dP_h}.\frac{P_h}{Y_i} = \frac{d^2\prod}{dP_i dP_h} = G_{ih}.\frac{P_h}{Y_i} \qquad (12)$$

for all i, h = 1, 2, …, m, and

$$E_{jk} = \frac{dX_j}{dR_k}.\frac{R_k}{X_j} = \frac{d^2\prod}{dR_j dR_k}.\frac{R_k}{X_j} = G_{jk}.\frac{R_k}{X_j} \qquad (13)$$

For j, k= m+1, m+2, …, n, where G_{jk} is the (j, k)-th element of the inverse of the Hessian of production technology. Equations (12) and (13) are termed Marshallian elasticities because they are not derived from an input or output-constrained function (Hicksian function) but are from an unconstrained profit function (Marshallian function). These elasticities signs are used to conclude whether outputs or inputs are gross substitutes (Eih > 0, Ejk < 0) or gross complements (Eih < 0, Ejk > 0).

2. Materials and Methods

2.1. Study data

The study used the 2010-2016 nationally representative Nigeria General Household Survey (GHS), extracted from the World Bank website. It was a production data panel survey of six (6) visits conducted during post-planting and post-harvest agricultural seasons in Nigeria. The three (3) waves consisted of two (2) visits to the household in each of the waves: the post-planting visit occurred directly after the planting season between August-October. The post-harvest visit occurred after the harvest season between February-April. This study was conceptualized, conducted and reported in accordance with the Research Ethics Policy of the Federal University of Agriculture Abeokuta, Nigeria.

This study focused on the analysis of output supply and input demand response based on the major field crops and factors of production. Thus, both the input and output categories were constructed. Three output categories were identified (crops, livestock, and non-farm income) following Ball (2002). However, the crop output category was further grouped into five (5) which were i. cereals, ii. pulses/seeds/nuts, iii. roots and tubers, iv. vegetables and fruits, and v. other crops/agricultural by-products. A total of seven (7) output categories (cereals, pulses, root crops, vegetables and fruits, other crops, animal products). Four (4) variable input categories (labour, agrochemicals, intermediate inputs, mechanisation were used for this study. Non-farm income was used as a reference group. Thus, the production response has 11 equations (7 output supply equations, and 4 input demand equations). Also, a time dummy variable was used to capture technological change.

2.2. Analytical techniques

This study made use of a profit function derived from the framework of profit maximization. This approach to the profit function requires detailed information on all input and output prices to examine the effects of these on farmers' resource allocation opinions. A duality relationship exists between profit and production function. Widely, the approach of duality was applied to provide a comprehensive relationship between inputs and output prices (Siregar 2007). The duality approach allows the estimation of the farm output supply and input demand grounded on flexible approximations of the profit function and/or the cost function (Chambers 1988; Diewert 1974). The duality approach states that the profit and production function describes the input demand and output supply response if both functions satisfy regular properties of monotonicity and convexity. Hence, a profit function can be treated as if it is derived from a production function (McFadden 1978).

Following Lau (1972) the normalized profit function was derived through the consideration of the production function with the neoclassical properties that describe the transformation of variable and fixed inputs into outputs. Linear homogeneity of degree one in prices of output and input, and symmetry restrictions were imposed a priori. The restricted profit function is approximated by the translog function:

$$\ln \prod_R^* = \alpha_0 + \alpha_i \sum_{i=1}^{m} \ln P_i + \beta_j \sum_{i=1}^{n} \ln X_j + {}^1/_2 \sum_{i=1}^{m}\sum_{j=1}^{m} \beta_{ij} \ln P_i \ln P_j + {}^1/_2 \sum_{j=1}^{n}\sum_{k=1}^{n} \delta_{jk} \ln X_j \ln X_k + \sum_{i=1}^{m}\sum_{j=1}^{n} \rho_{ij} \ln P_i \ln X_j + \sum_{i=1}^{m} \gamma_{it} \ln P_i t + \sum_{j=1}^{n} \emptyset_{jt} \ln X_{jt} + \theta_t t + {}^1/_2 \theta_{it} t^2 \quad (14)$$

Where:

$\prod_R^* =$ Restricted profit, normalized by cereal output price (P_1)

P_i= normalized output prices for the other output categories

X_j= normalized input prices of the inputs categories (labour, biochemical, intermediate inputs, and mechanisation)

t= period (time trend)

α_0 , α_i , γ_{ij} , δ_{ik} , β_k and θ_{kh} are parameters estimated.

ε= Random error

The partial derivatives of the profit function to output price or input price yield a system of output and input share equations using Hotelling's lemma.

$$d \ln \Pi^* /_{d In P_i} = \frac{P_i X_i}{\pi} = S_i \quad (15)$$

When equation (14) is applied to equation (15), yields this share equation:

$$S_i = \alpha_i + \sum_{j=1}^{m} \beta_{ij} In P_j + \sum_{j=1}^{n} \rho_{ij} In X_j + \gamma_{it} t, \quad i = 1, \ldots \ldots, m \quad (16)$$

Since, both the input and output share equations come from a single profit share equation. Therefore, the cereal share equation was dropped and share equations were estimated jointly using the Seemingly Unrelated Regression (SURE) procedure. Joint estimation of the input demand equations and output supply equations ensures consistent parameter estimates (Ball 1988).

The multiple input–multiple output (MI-MO) framework, is based on the premise that crop production decisions are related to those of other crops. Hence, the error term of one equation is correlated to those of other equations. This makes ordinary least squares (OLS) not applicable in the estimation of the share equations. Also, because of the imposition of the cross-equation restriction, OLS is not appealing. The correlation and cross-equation restriction can be overcome by using SURE.

Equation (3) is the final estimation used for this study. The parameters were estimated jointly using an iterative SURE procedure of SHAZAM (Window Professional). The restricted model is one where the homogeneity and symmetry conditions are imposed.

2.2.1. Estimation of own and cross-price elasticities

The second-order derivatives of the profit function yield the input and output response elasticities (Weaver 1983). The own-price and cross-price elasticities respectively are:

$$\eta_{ii} = \left({}^{\beta_{ii}}/_{S_i} \right) + S_i - 1 \quad (17)$$

$$\eta_{ij} = \left({}^{\beta_{ii}}/_{S_i} \right) + S_j \quad (18)$$

Where:

η_{ii}= own price elasticity

η_{ij}= cross price elasticity

S_i= ith share equation, at the sample mean

3. Results and Discussion

3.1. Description of farm households production data

The GHS captured three major income-generating activities in Nigeria which were agricultural production, wage employment, and non-farm livelihood activities. Table 1 shows that agriculture (52.5%) is the most common activity in post-planting. This was followed by non-farm activities (20.8%) and wage employment (12.6%). However, in the post-harvest, nonfarm enterprises and wage employment were common. Household involvement in agriculture was much lower (37.4%). This indicated that post-harvest is a season of inactivity between harvest and planting for the next season. Besides, agricultural activities are the dominant jobs of rural farmers while non-farm enterprises are more common for urban farmers. In the post-planting season, North East and North West zones (65.78% and 62.82% respectively) had the highest participation in agricultural activities, also in post-harvest visits (45.82% and 47.34%). North Central and North East held an average of 3.2 and 3.0 plots of

Table 1. Farm households' characteristics in Nigeria

Characteristics	North Central	North East	North West	South East	South-South	South West	Urban	Rural	Pooled
Main Income Generating Activities									
Post-planting period									
Agriculture (%)	58.6	65.7	62.8	48.9	38.8	35.7	30.9	66.5	62.5
Wage employment (%)	25.6	13.2	22.7	20.1	17.8	24.2	24.2	19.3	30.8
Nonfarm Enterprise (%)	10.8	9.3	7.4	20.3	18.4	15.3	18.3	8.6	12.6
Post-harvest period									
Agriculture	44.5	45.8	47.3	24.3	18.5	13.8	10.8	36.6	47.4
Wage employment	15.4	19.3	20.4	15.6	25.2	23.6	18.4	15.8	18.5
Nonfarm Enterprise	11.6	8.9	7.7	12.7	16.1	17.8	17.1	8.56	10.8
Farm Plot Holdings									
Number of Farm Plots	3.5	3.0	2.5	2.3	2.7	2.8	2.3	2.5	2.5
Average Farm Size (Hectares)	0.6	0.7	0.5	0.4	0.4	0.8	0.4	0.9	0.7
Farm Input Use									
% Fertilizer	28.5	50.7	92.8	46.8	8.0	9.3	44.6	48.2	47.8
% Pesticide	10.2	17.4	46.3	5.6	4.0	35.3	20.9	20.7	20.7
% Herbicide	48.2	45.7	30.0	7.0	15.8	30.2	30.0	30.6	30.5
%Purchased Seed	12.5	12.8	33.2	37.7	19.4	15.2	32.8	21.5	22.6
% Animal Traction	4.6	54.8	45.5	0	0	0	10.0	23.1	21.5
Average Workdays of Household Labour	186.4	185.5	146.9	90.6	102.3	96.2	92.4	148.2	128.3
Average Workdays of Hired Labour	45.2	28.3	54.8	20.11	25.5	70.42	30.2	42.6	44.2
Major crop grown (%)									
Cereals	31.5	58.8	30.5	24.4	23.5	15.0	40.7	34.2	45.4
Pulses	36.9	28.5	13.2	16.4	16.2	18.3	24.4	18.3	30.2
Roots and Tubers	78.3	55.2	19.5	14.5	28.3	20.9	44.6	30.4	40.5
Fruits and Vegetables	34.6	21.3	33.2	30.4	33.3	20.4	26.3	22.1	27.6
Livestock Ownership (%)									
Calf(male)	2.32	5.8	2.5	0	0	0	0	2.7	2.2
Calf(female)	2.14	5.3	3.5	0	0	0	0	3.0	2.6
Cow	17.2	23.5	21.0	1.1	0.2	2.5	6.5	16.5	15.4
Bull	7.6	15.6	15.4	0	0	0	1.4	11.0	9.2
Ox	2.5	19.4	3.8	0	0	0	0.4	5.9	5.2
Goat	61.2	72.1	79.1	56.0	45.8	53.7	58.8	68.7	67.3
Sheep	18.5	42.1	57.8	6.9	0.7	4.9	24.3	34.2	33.0
Chicken(local)	73.9	66.4	55.5	74.2	60.2	68.3	55.5	65.2	64.8
Duck	4.3	8.5	1.3	0	2.3	2.5	1.6	3.2	3.0
Guinea fowl	1.3	4.2	9.8	0	0	0	1.2	4.8	4.4
Utilization of Livestock									
Sales	24.4	45.3	20.5	36.0	32.6	21.2	24.3	28.9	28.5
Slaughter	29.5	38.9	19.2	37.9	29.2	36.1	29.2	29.0	29.0
Others	0.4	2.4	0.9	1.1	0.8	1.0	0.5	1.2	1.1

Source: computation from LSMS Panel Data (2010-2016).

farmland respectively. The average farm plot size is less than 1 hectare for Nigeria. Average farm size in rural (0.9 hectares) areas were larger than in urban (0.4 hectares) areas. The northern region's farm sizes were generally larger than those in the southern regions.

Information on farm input use across zones revealed that 47.3% of the households used fertilizers, 20.7% used pesticides, 30.5% used herbicides, 22.9% used purchased seeds, and 21.4% used animal traction on their farm plots. However, farm plots operated by rural households utilized more fertilizer, herbicide, animal traction, and labour, than those operated by urban households. Households in urban areas used more pesticides and purchased seeds than those in rural areas on their plots. Moreover, labour input use captured by workdays showed that average household labour workdays (128.3) are larger than that of hired labour workdays (44.2). Crop cultivation is dominated by rural farmers. Maize is mostly cultivated, accounting for the highest (45.4%) household participation in all the crop cultivation categories. Followed by roots and tubers (40.5%) and pulses (30.2%).

The number of livestock by type of animal and geographical region revealed that goats (66.8%) and chickens (63.6%) were commonly owned animals, followed by sheep (33.1%), and cows (15.1%). By region, goats and chickens were mainly owned. Also, 29% of livestock-owning households slaughtered, 28.5% sold, and 1.1% used livestock for debt payment.

3.2. Testing of the production technology properties

The estimation of the share equations was the first step in testing the production technology properties. The parameter estimates of the seemingly unrelated regression technique of supply response to changes in both output and input prices as presented in Table 2. Nine of the ten own-price coefficients were significant at the 1% level. A total of sixty-five (65) parameters were contained in the table, out of which, forty-six (46) were significant at various levels. The coefficients of cross-price were the most significant, and the time trend coefficients were generally significant. Time trends that captured the level of technology had a significant and positive effect on fruits and vegetables, other foods, biochemical inputs, intermediate inputs, and mechanisation and were negatively significant for roots and tubers, and labour. There was no structural change in the production of cereals and pulses because both coefficients were statistically insignificant.

In addition to the imposed properties of symmetry and homogeneity, the other properties of a profit function that globally cannot be satisfied with the translog function were monotonicity and convexity (Fulginiti and Perrin 1990). Monotonicity and convexity were checked after the estimation. Monotonicity entails that the fitted values of the supply of output are positive and input demand equations are negative. However, the monotonicity restriction is violated if the predicted output shares are negative and/or input shares are positive. Also, the convexity necessary condition is that all the own-price elasticities must have the expected signs (positive). The adding-up property is satisfied since the functions are specified in share form.

3.3. Elasticities of input demand and output supply

The own and cross-price elasticities of output supply and input demand equations obtained directly from the profit function estimates are shown in Table 3. Model estimation subjected to the theoretical restrictions ensures that own-price elasticities of output supply are positive and negative for input demand. The expected positive signs of the own-price elasticities of output supply were consistent for profit maximization.

The own-price elasticities of cereals, pulses, and other foods supply were elastic while that of roots and tubers, fruits and vegetables, and animal products ranges between 0.54 and 1.31. The inelastic nature of own-price elasticities of roots and tubers (0.6859), fruits and vegetables (0.6818), meats, and animal products (0.5402) implies that qunatity produced were less responsive to their price change (increase) when compared with other output categories that were elastic. However, cereals, pulses, and other foods were more sensitive and responded quickly to, price changes. Anand et al. (2016) posited that supply is perfectly elastic in output prices and that it is the input demand that adjusts to clear markets.

Since this study is based on multiple outputs and multiple inputs frameworks, the cross-output supply elasticities became more appealing allowing the identification of substitution and complementarity possibilities among the output and input categories specified. In terms of elasticities of output cross-price, 65% of them were positive, suggesting a complementary relationship between the output supplies. The gross complementarity of output categories would increase the production of all outputs. This would occur if the input usage increase resulted from an output price increase which sufficiently shifted the production transformation frontier outward to allow absolute price increase implying that, as the commodity price rises, new inputs are drawn into the production given that the input elasticities in response to output prices, promoting an increase in the production of other outputs as well.

Given the output price elasticities in Table 3, if a general rise in output prices is not offset by higher input prices, a relatively elastic response output would be induced, but it will not equally affect all the commodities (Fulginiti and Perrin, 1990). However, cross-price elasticities between cereals and pulses, cereals, and roots/tubers were negative, suggesting the competitive relationship between output supplies of cereals and pulses; cereals, and roots/tubers.

Output supply elasticities to input prices were inelastic and mainly positive, implying that an increase in the output price would lead to an increase in input demand to produce more.

The estimated input demand results revealed that the own-price elasticities of all input demand have expected negative signs, and were price elastic except mechanisation input demand. The own-price elasticities of labour, agrochemicals, and intermediate inputs demand were elastic and negative ranging between -1.14 to -1.48 implying a high degree of responsiveness to input price, and that the labour farm employment level may dramatically decrease as a result of a wage increase.

Besides, the gross complementarity of the input pairs suggested a reduction in output would be accompanied by reductions in the demand for all production factors. A general rise in input prices, with output prices constant, would result in a reduction of the use of labour, agrochemicals, and intermediate inputs much more than any other input (mechanisation). The magnitude of these elasticities suggests that policy issues affecting labour wages, intermediate inputs, and agrochemicals will not have a noticeable effect on output levels as well as input use.

As for the estimated cross-price elasticities, there is the existence of input/output prices on input demand and output supply of cross-effects. This cross-effects relationship justifies the multiple outputs- multiple input (MO-MI) nature of the crops, and the course, of the analyses in the present study. Comparing the output supply own-price elasticities, and the input demand own-price elasticities were higher, in absolute terms. This indicated that policy on commodity prices of both outputs and inputs may be effective, and hence should be implemented directly. However, such policy should be politically desirable, and focus more on production inputs than outputs as higher magnitudes were found for input demand than output supply.

4. Conclusion and Recommendation

Studies have argued that farmers do not respond to economic shocks such as price and income, particularly in less developed countries. This study examined farm input demand and output supply response to price shocks using the restricted translog profit function by estimating both the revenue and cost shares model and imposing appropriate restrictions. The own-price inelastic nature of the food crop supply in Nigeria particularly roots/tubers and fruits/vegetables implied that farmers' revenue decreases as more of the quantity produced were increased.

The own-price elastic nature of input demand of biochemical and intermediate inputs suggested that efforts to increase input prices through removal of price subsidy, would significantly reduce the utilization of the inputs, and also decrease inputs producer’s revenues.

Table 2. Seemingly unrelated regression parameter estimate for share equations

	Output Share Equations						Input Share Equation				
Explanatory Variables	**Cereals**	**Pulses**	**Roots & Tuber**	**Fruits & Vegetables**	**Animal Products**	**Other Food**	**Non-farm**	**Labour**	**Biochemicals Inputs**	**Intermediate inputs**	**Mechanisation**
Constant	-0.516	0.005***	0.439***	0.041***	0.009	0.002	0.001	0.551***	0.048***	0.397***	0.025***
		(3.65)	(47.46)	(5.58)	(0.68)	(0.27)	(0.40)	(87.90)	(7.00)	(62.87)	(4.81)
Cereals	**0.139**										
Pulses	0.016	**-0.031*** **									
		(-4.54)									
Roots & Tuber	-0.176	-0.054***	**0.003*** **								
		(-12.31)	**(43.76)**								
Fruits & Vegetables	0.006	0.023***	-0.024***	**0.007***							
		(6.39)	(-10.08)	**(1.93)**							
Animal Products	0.008	0.052***	-0.079***	-0.004	**0.036*** **						
		(10.12)	(-20.89)	(-1.18)	**(5.08)**						
Other Food	0.006	0.025***	-0.015***	0.006***	-0.001	**-0.006** **					
		(9.38)	(-7.45)	(2.56)	(-0.17)	**(-2.24)**					
Non-farm	0.001	0.001	-0.005***	0.001	0.005***	-0.002**	**0.002***				
		(0.94)	(-5.21)	(0.49)	(3.33)	(-2.24)	**(1.74)**				
Labour	0.005	0.003	0.013***	-0.003**	-0.006**	-0.002	-0.000	**0.045*** **			
		(1.09)	(4.56)	(-2.11)	(-2.26)	(-1.08)	(-0.58)	**(16.67)**			
Biochemicals	-0.005	0.011***	-0.012***	0.009***	-0.012***	0.001	-0.000	-0.007***	**0.005***		
		(3.60)	(-4.48)	(4.53)	(-2.24)	(0.46)	(-0.12)	(-3.41)	**(1.92)**		
Intermediate Inputs	0.009	-0.015***	0.005*	-0.006***	0.026***	-0.001	-0.000	-0.037***	0.005**	0**.028*** **	
		(-5.11)	(1.93)	(-3.54)	(9.86)	(-0.45)	(-0.19)	(-17.58)	(2.43)	(9.73)	
Mechanisation	-0.008	0.005**	-0.006***	0.001	-0.007***	0.000	-0.000	-0.001	-0.005***	0.003**	**0.002**
		(2.23)	(-3.78)	(0.46)	(-2.94)	(0.08)	(-0.38)	(-0.65)	(-3.07)	(2.44)	(1.16)
Time	0.027	0.015	0.011***	-0.004***	0.002	0.003***	-0.000	-0.017***	0.013***	0.003***	0.002***
		(1.50)	(7.402)	(-5.53)	(1.37)	(4.61)	(-1.54)	(-17.84)	(12.57)	(2.9)	(3.98)
System R2		0.063	0.181	0.012	0.045	0.015	0.004	0.095	0.043	0.043	0.003

Note: 1. The parameters of the share equation for cereals products were calculated using the constraints implied by linear homogeneity in prices 2. values in parentheses are t-statistics. 3. ***, ** and * imply the associated coefficient is significant at 1%, 5% and 10% levels respectively 4. Single equation measures ??of fit? are not generally applicable in systems estimation.

Table 3. Farm output supply and ınput demand elasticities

	Output Supply Equation							**Input Demand Equation**			
Categories	Cereals	Pulses	Roots and Tubers	Fruits and Vegetables	Animal Products	Other foods	Nonfarm Income	Labour	Agrochemicals	Intermediate inputs	Mechanisation
Cereals	**1.246**	-1.680	-0.142	0.680	0.514	0.738	0.533	-0.442	0.355	-0.452	-0.095
Pulses	-0.147	**1.164**	-0.067	0.927	0.615	1.490	0.267	-0.118	-0.278	-0.077	0.313
Roots & Tubers	-0.101	-0.186	**0.685**	-0.641	-0.486	-0.510	-0.309	-0.333	0.120	-0.318	-0.030
Fruits & Vegetables	0.039	0.207	-0.052	**0.681**	-0.018	0.337	0.103	-0.017	-0.155	-0.011	0.055
Animal Products	0.118	0.550	-0.158	-0.075	**0.540**	0.070	0.790	-0.086	-0.085	-0.156	-0.176
Other foods	0.031	0.244	-0.030	0.247	0.012	**1.129**	-0.273	-0.015	0.029	-0.016	0.022
Non-farm Income	0.009	0.018	-0.007	0.031	0.060	-0.113	**0.797**	-0.006	-0.006	-0.007	-0.002
Labour	-0.467	0.484	0.497	0.318	0.398	0.374	0.408	**-1.150**	0.348	-0.375	-0.421
Biochemicals	0.055	0.167	-0.026	0.420	--0.057	0.108	0.054	0.051	**-1.445**	0.079	-0.116
Intermediate inputs	0.472	-0.314	0.469	0.213	0.710	0.416	0.434	-0.371	0.531	**-1.487**	-0.583
Mechanisation	0.005	0.070	0.002	0.056	--0.044	0.031	-0.009	-0.023	-0.043	-0.032	**-0.850**

Source: Author’s Computation, 2019

inputs would lead to less efficient utilisation of the agrochemical and intermediate inputs. In addition, the possible increase in the agrochemical and intermediate inputs prices after the removal of subsidy would create incentives (higher prices) for the producers and traders of the inputs. The inelastic nature of mechanisation suggests that attempts to increase its prices would not significantly reduce its utilisation. Therefore, considering the vulnerable nature of food crop farmers to input prices in Nigeria, such a reduction should be undertaken gradually.

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Agricultural credit supply and the performance of microfinance institutions in southern Togo

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ABSTRACT

The problem of underfinancing in the agricultural sector has always been a subject of consideration for governments. Thus, for decades, programs have been implemented to eradicate poverty and facilitate access to financial services for the most disadvantaged segments of the population, represented mainly by the rural population. Among these programs, microfinance holds a predominant place. However, the latter is increasingly moving away from the agricultural sector, depending on its assessment of the risky nature of agricultural investments. This study sought to analyze the effect of agricultural credit supply on the performance of microfinance institutions (MFIs). Data from the two largest microfinance institutions (FUCEC-Togo and WAGES) were analyzed. The linear regression model was used for the analysis. The results show that the supply of agricultural credit has a negative impact on financial performance ratios of both MFIs in this study. The study recommended that microfinance institutions improve their agricultural financial services to adapt them to the needs of rural populations. The introduction of financial products should be adapted to the needs of producers and compatible with the profits of microfinance structures.

1. Introduction

The agricultural sector in Togo contributes extensively to the economic development of the country. Thus, the problem of underfinancing has always been the subject of consideration by various governments. According to Adessou et al. (2017), several studies were conducted between 2008 and 2012 to assess the constraints of the agricultural finance sector in Togo and to propose appropriate solutions at the request of the Ministry of Agriculture and the UNDP. These studies have proposed various financing mechanisms for the rural sector, both for farmers but also for small businesses in the sector, such as the establishment of a "Fund for Agricultural Development" and a "Guarantee Fund for Agricultural Investments." However, these recommendations have not led to the establishment of public or private mechanisms for sustainable finance in agriculture.

Despite its importance for poverty reduction, the agricultural sector has little or no access to financial services. Nowadays, banking institutions are mainly located in urban areas and do not finance the rural sector, especially not small-scale farmers without the necessary guarantees (land title, direct debit, etc.), to apply for a loan (Adessou et al. 2017). Given the exclusion or insubstantial consideration of the agricultural sector by banks or traditional financial institutions, microfinance is the most important financing source for agriculture in developing countries (Sossou et al. 2017). The microfinance sector has been booming for the past ten years in Togo. According to data from BCEAO (2020), the number of beneficiaries (clients) of MFIs rose from 1.6 million to 2.6 million between 2015 and March 2019. Each year, transactions (credits and deposits) exceed $540 million.

In Togo, as in most West African countries, many microfinance institutions have ignored the underfinancing problems of the rural sector. According to Adessou et al. (2017), in addition to the geographic distance of MFIs from rural areas, which remain concentrated in urban areas, their loan-accessing conditions frequently exclude many farmers.

Several studies have looked at the determinants of the financial performance of microfinance institutions (Adongo and Stork 2005; Tehulu 2013; Ibrahim 2015; Bui 2017; Kanyenda 2019; Gadedjisso-Tossou et al. 2021), etc. According to Adongo and Stork (2005) the viability of the evaluated microfinance institutions is provided by the support funds from donors. For Tehulu (2013), the size of the microfinance and loan intensity, the efficiency of the management staff and the portfolio at risk are the main factors influencing the financial sustainability of East Africa microfinance institutions. According to the findings of Ibrahim (2015) risk-assessing factors such as risk coverage, write-off ratio and outreach indicators e.g. the number of active borrowers and the average loan size, are the determinants of the sustainability of microfinance institutions in Togo. Gadedjisso-Tossou et al. (2021), also mentioned social responsibility (CSR) as a relevant factor for the sustainability of microfiance institutions. Few studies have examined the performance of microfinance institutions concerning the agricultural credit supplies. Empirical studies on agricultural credit and the performance of microfinance institutions are almost nonexistent in Togo. Given the importance of access to agricultural credit and the role of microfinance institutions, it is necessary to investigate this subject, which is of vital importance. Thus, certain performance ratios of microfinance institutions were analyzed to evaluate the role of agricultural credit supplies.

Investors and government supervisors evaluate the achievement in terms of financial return of microfinance institutions, financial performance is one of the indicators employed (Rosenberg et al. 2003; Bui 2017). According to the literature, the performance of an institution can be viewed from two angles namely: social and financial performances. According to Boye et al., cited in (Fersi and Boujelbéne 2016), social performance measures the MFI's intent to have a social impact and provide a suitable integration in its operation area which highlights the vision of the microfinance institution to fight and eradicate poverty in the community. The social performance itself can be separated into four dimensions: targeting and outreach, adaptation, and quality of services, economic benefits, and social responsibility (Amersdorffer et al. 2015).

Financial performance is the capacity of a microfinance institution to meet its expenses with its income and finance its growth Fersi and Boujelbéne (2016). Financial performance, which is the subject of our study, has attracted a lot of interest from analysts and researchers because it is a key point in achieving the financial sustainability of microfinance institutions. According to Bui (2017), all microfinance institutions need to achieve good financial performance, i.e., must be profitable over the long term to be self-sustaining. Profitability allows an MFI to continue operating and growing.

To assess the financial performance of microfinance institutions, various indicators have been used by different authors. Thus some authors used profitability ratios such as return on asset (ROA) and sustainability ratios like operational self-sufficiency and financial self-sufficiency (Cull et al. 2007; Crombrugghe et al. 2008; Quayes 2015; Fersi and Boujelbéne 2016). On the other hand, some authors have only used profitability ratios to understand the financial performance of microfinance institutions. Given the structure of this paper and according to the findings of some previous research only the return on assets ratio will be used in this paper as a proxy for the analysis of the financial performance of microfinance institutions.

The term “financial viability” in the microfinance sector is often used by many authors to refer to financial sustainability and financial self-sufficiency. As we will see, for some, financial viability is a component of financial sustainability. Thus, according to Ledgerwood (1999), microfinance is considered to be financially viable when it meets its costs with earned revenue. This implies that microfinance relying on donor funds to run its operation cannot achieve financial viability. Self-sufficiency indicators are used to evaluate the financial viability of microfinance institutions. Financial self-sufficiency and operational self-sufficiency are the two levels of self-sufficiency employed to compare MFIs (Ledgerwood 1999).

Christen et al. (1995) suggested three degrees of self-sufficiency be gradually achieved by an MFI. The first one should be operational self-sufficiency. It occurs when the operating revenue covers both the operating costs and the loan loss provision. The second degree is the ability of the MFI to meet its financing costs, operating expenses, and loan loss provision from the earned revenue. The last one, financial self-sufficiency, means the institution can cover both non-financial and financial expenses. Zerai and Rani (2011) listed operational self-sustainability and financial self-sustainability as the two degrees of financial sustainability for an MFI to achieve. The first is reached at the moment when the “institution earns sufficient income from its own earned revenue sources to cover all administrative or operational expenses but relies on a wholly or partially subsidized capital base”. The operational sufficiency indicator is the one most commonly used for this purpose. Operational self-sufficiency is equal to the ratio of total operating income to total operating expenses (including administrative expenses, interest expenses, and loan loss provisions). The last one is reached when the microfinance institution has enough profits to be able to meet all its operating expenses, the inflation cost, its loan losses, and the market cost of funds. Here, the adjusted return on assets ratio is employed.

Finally, the MIX Market defines the term financial sustainability as having an operational sustainability level of 110 percent or more, while operational sustainability is defined as having an operational self-sufficiency level of 100 percent or more. But Meyer (2002) indicated, "Measuring financial sustainability requires that MFIs maintain good financial accounts and follow recognized accounting practices that provide full transparency for income, expenses, loan recovery, and potential losses."

2. Materials and Methods

This study focuses on microfinance in southern Togo. Given the difficulties of collecting data, only the FUCEC and WAGES microfinance institutions located in the south of Togo, more precisely in Lomé, and their branches throughout the country, are the subject of this study. According to an anonymous source, in 2010, the microfinance sector in Togo was heavily dominated by FUCEC, which accounted for 60% of the sector's activity across all parameters, followed distantly by WAGES with 15%. Thus, these two microfinance institutions represent about 75% of the national market share and have more branches serving the agricultural sector.

2.1. Econometric model

Since the data for this research are in the longitudinal form commonly called panel data, we need an appropriate model. The general model can be written as follows:

$$Y_{it} = \beta X_{it} + \varepsilon_{it} \qquad [1]$$

Where Y_{it} represents the value of the dependent variable of unit i at time t (i= 1 …. N and t= 1…T), X_{it} represents a vector of explanatory variables and β its coefficients, and ε_{it} is the error term.

This model has a double dimension, so two variation schemes are proposed. These are the fixed effect model and the random effect model.

Fixed effects model:

The model is presented as follows;

$$Y_{it} = \alpha_i + \beta X_{it} + \varepsilon_{it} \qquad [2]$$

In this first model, we assume the uniformity of the coefficients from one individual to another except for the constant. α_i individual effect that is constant over time but specific to each individual.

Random effects model:

$$Y_{it} = \beta X_{it} + \mathcal{E}_{it} \qquad [3]$$

With $\mathcal{E}_{it} = \alpha_i + \square_{it}$ which are uncorrelated random disturbances. These are the individual effect (individual-specific disturbance) and the residual effect respectively.

2.2. Model specification

In an analysis of the financial performance determinants of microfinance institutions, different ratios or indicators of sustainability are used as dependent variables. Cull et al. (2007); Bogan (2009); Zerai and Rani (2011); Ibrahim (2015); Bui (2017) among others, have examined the financial performance of microfinance institutions using the operational sustainability ratios of ROA (Return On Asset) and ROE (Return On Equity).

This study only uses the operational sustainability ratio as well as the ROA to reach its objectives. These two ratios were chosen because they are the ones that allow the comparison of microfinance structures on the same basis and because their interpretation remains the same regardless of the microfinance structure.

Extending equation 1 and after defining the variables (Table 1), the following regression model was obtained:

$$ROA_{it} = \beta_0 + \beta_1(\text{CREDAGR}_{it}) + \beta_2(\text{CPB/GNI}_{it}) + \beta_3(\text{OETA}_{it}) + \beta_4(\text{PROD}_{it}) + \beta_5(\text{INFRAT}_{it}) + \mathcal{E}_{it} \qquad [4]$$

With i= 1..2 and t= 2014 to 2018.

This same model was estimated for the operational sustainability variable.

3. Results and Discussion

This chapter presents the results of the statistical and econometric analyses. The purpose is to analyze the effect of agricultural credit supply on the financial performance of microfinance institutions.

3.1. Descriptive statistics

As shown in Table 2 below, the operational sustainability variable has a mean of 1 with a minimum and maximum of 0.789 and 1.192 respectively. The variable Return on Asset has a mean of 0.003 with a minimum of -0.04 and a maximum of 0.0279. The mean of the operational sustainability ratios of the two microfinance institutions studied undermines the institutions' good control over their operating expenses and income. In contrast, the low return on asset ratio is proof of the misuse of the majority of the microfinance assets, leading to economic losses. As for the variable CREDAGR, its average is 3 with a minimum of 0.995 and a maximum of 6.44. The agriculture credit variable, according to the needs of the sector is very low and shows a decline year after year. The variables CPB/GNI, OETA, PROD, and INFRAT have a mean of 0.159; 0.122; 127.25, and 0.176 respectively.

3.2. Econometric analysis result

Based on the data structure used in this study, which is unbalanced panel data, it is necessary to determine if random effect or fixed effect best fits our model. Using STATA, the Hausman test was performed and the result was not significant which led us to choose the random effect model as more appropriate for the purpose. Further, the LM test is used to compare whether the random effect regression model is better than the simple OLS regression. The prob. value of the chi-square in the LM test is greater than 0.05, which shows the null hypothesis is accepted and the alternative is rejected. Therefore, the OLS regression model is an appropriate model for this study. Correlation and multicollinearity analysis were carried out. The results are presented in Table (3) and (4) in the appendix.

As presented above, two ratios were used to achieve the objectives of this section. For each ratio, two models were estimated. The first one includes all variables and the second one excludes the country's inflation rate variable.

3.2.1. Return on asset

In the first model (Table 5), only two variables (operational expenses on total assets and the productivity ratio measured by borrowers per staff member) significantly influence the return on asset ratio of the two microfinance institutions analyzed in this study. These two variables have a negative influence on the ROA of the two microfinance institutions and are statistically significant at the 10% level. All other things being equal, any increase in these ratios would lead to a decrease in the ROA of these two structures. These findings can be explained by the fact that the use of the institutions' assets is not providing enough return compared to the expenses. Furthermore, the institution's staff is not efficient enough in serving its customers on time. Most of the time, clients complain about the slow processing of their loan applications, according to anonymous sources. This result confirms that of Kar and Swain (2013); who found a negative correlation between the ROA and the operating expense ratio. On the other hand, this result contradicts that of Bui (2017) who found a positive and significant relationship between the management efficiency ratio (OETA) and ROA.

Table 1. Model variables

Variables	Definition and measurement	Predicted signe
Dependent	ROA= Return On Asset (Net Operating Income - Taxes) / Average Total Assets	
	OS= Operational sustainability (operational self-sufficiency level of 100% or more)	
Independent variable	CREDAGR= the value of agricultural credit in the portfolio of MFIs.	+/-
	CPB/GNI= Cost per borrower/GNI per capita ratio (%) (CPB is a cost per borrower for firm i, in period t)	-
	OETA= Management inefficiency, Operating expense to total asset	+
	PROD= is the productivity of firm i, in period t, which is measured by borrowers per staff member	+
	INFRAT= The country's inflation rate.	-

Table 2. Descriptive statistics

Variables	Mean	Std Dev	Min	Max
OS	1.063	0.144	0.789	1.192
ROA	0.003	0.023	-0.040	0.027
CREDAGR	3.630	2.356	0.995	6.440
CPB/GNI	0.159	0.034	0.133	0.237
OETA	0.122	0.071	0.077	0.286
PROD	127.250	28.694	73	175
INFRAT	0.176	0.030	0.132	0.215

Table 3. Variance inflation factor

Variables	VIF	1/VIF
CREDAG	2.248	0.445
OETA	2.048	0.488
CPB/GNI	1.099	0.910
PROD	1.072	0.930
Mean VIF	1.617	.

Table 4. Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)
(1) ROA	1.000				
(2) CREDAG	-0.557	1.000			
(3) PROD	-0.575	-0.228	1.000		
(4) CPB/GNI	0.112	-0.277	0.151	1.000	
(5) OETA	-0.716	0.710	-0.099	-0.139	1.000

Table 5. Econometric model results

	ROA1		ROA2		OS1		OS2	
Variables	**coef**	**p-value**	**coef**	**p-value**	**coef**	**p-value**	**coef**	**p-value**
CREDAG	-0.003	0.339	-0.003	0.066*	-0.021	0.234	-0.030	0.028**
CPB/GNI	0.056	0.586	0.039	0.496	0.181	0.765	-0.168	0.675
OETA	-0.195	0.065*	-0.186	0.011**	-1.026	0.085*	-0.837	0.039**
PROD	-0.001	0.053*	-0.001	0.002***	-0.003	0.064*	-0.004	0.003***
INFRAT	0.041	0.812	-	-	0.855	0.453	-	-
Cons	0.089	0.240	0.104	0.003***	1.464	0.047*	1.758	0.000***
	R-squared	0.985	R-squared	0.985	R-squared	0.986	R-squared	0.980
	F-test	27.141	F-test	49.069	F-test	28.055	F-test	36.653
	Prob > F	0.036	Prob > F	0.005	Prob > F	0.035	Prob > F	0.007

Note: ***: 1% significance; **: 5% significance; *: 10% significance.

In the first model, the agricultural credit variable, although having a negative coefficient, is not statistically significant. The negative sign of the coefficient implies that this variable would have a negative impact on the return on assets of these two structures. In the second model, the inflation variable was excluded. In addition to the two previous significant variables, we find that the agricultural credit variable is now statistically significant. All three variables have negative coefficients, which imply that any increase in these variables would have a negative influence on the return on assets of microfinance. As in the first model, the agricultural credit variable has the same coefficient and is statistically significant at 10%. According to this result, any augmentation of 1 million dollars of the fund allocated to the agricultural sector will decrease the return on asset ratio of the microfinance institutions by 0.3%. This can be explained by the fact that the low population density in rural areas increases the need for assets and the expenses to provide financial services but at the same time the repayment rate is general very low (Avocevou 2003). This can justify the unwillingness of some microfinance institutions to serve the rural sector. However, according to some microfinance experts, nowadays it is the knowledge that some institutions have of the agricultural credit services that make the difference in the results at the end of the year.

3.2.2. Operational sustainability

The first estimation results show that only management efficiency (OETA) and productivity have a significant impact on the operational sustainability ratio. The negative sign of their coefficients indicates the opposite direction of this impact. An increase in these variables would lead to a decline in the operational sustainability ratio of these microfinance institutions. This result is confirmed by the findings of Rai et al. (2012); Kar and Swain (2013); Tehulu (2013); Heng (2015); Hossain and Khan (2016); and Usman et al.(2016) who also found a negative influence of the operating expense ratio on operational sustainability. Operating expense indicates the cost of providing services (loans) to generate revenue. Operating expense/assets provide a more accurate picture of the average performing assets for those MFIs that mobilize deposits. It covers the efficiency of the specific cost elements such as salaries and benefits as well as occupational expenses such as rent utilities and travel against the total assets. The inefficiency of handling operations for giving deposits and loans to customers can have a negative impact on MFI (Heng 2015).

Here again, the coefficient of the agricultural credit variable has a negative sign but is not statistically significant. In the second estimation, the agricultural credit variable still has a negative coefficient and is statistically significant at the 5% level. This implies that any increase of 1 million dollars in the value of agricultural credit in the portfolio of these microfinance institutions would lead to a decrease of 3% in the operational sustainability ratio. As in the first estimation, the variables management efficiency and productivity also have negative coefficients, which indicate the negative impact of their increase on the operational sustainability ratio. The reason justifying these findings is the same as in the case of the return on asset ratio.

4. Conclusion

The results of these analyses show us that the supply of agricultural credit has a negative impact on the two financial performance ratios of the MFIs in this study. In fact, according to the negative sign of the coefficients of this variable, we can conclude that any increase in the supply of agricultural credit in the portfolio of these microfinance institutions would worsens financial performance. This could justify the decline in microfinance structures vis-à-vis the agricultural sector. Although the two structures studied are the largest in terms of market share and financial services offered, the insufficiency of the data used in this research does not allow for generalizing the results of this research. There is therefore a lack of detail that would allow us to confirm the detrimental nature of the agricultural credit offer on the financial performance of microfinance structures. It would be even more interesting to obtain data from several microfinance institutions on the 30- and 90-day PAR for the agricultural sector, the repayment rate of agricultural loans, the write-off ratio, the loan loss rate for the agricultural sector, and many other variables over a longer period. It should also be noted that the variables most likely to influence the ROA are missing from our data. One can at least agree on the innovative character of this study which opens the way for other observation on the subject.

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