REPUBLIC OF TURKEY
ERCIYES UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF AGRICULTURAL SCIENCES AND TECHNOLOGIES

ANALYSIS OF ECONOMIC AND TECHNICAL EFFICIENCY OF SUNN PEST MANAGEMENT AND ITS IMPACT ON WHEAT PRODUCTIVITY IN IRAQ

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M. Sc. Thesis

June 2019
KAYSERI

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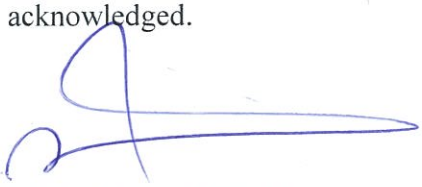
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June 2019
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SCIENTIFIC ETHICS SUITABILITY

I, Ziad Abbas Jassam, hereby declare that this piece of work is the result of my research and that this work has never been submitted anywhere for any degree. All the sources of information used were obtained in accordance with academic ethics and have been duly acknowledged.



Ziad Abbas JASSAM

SUITABILITY FOR GUIDE

The M.Sc. thesis entitled **"Analysis of Economic and Technical Efficiency of Sunn Pest Management and Its Impact on Wheat Productivity in Iraq"** has been prepared in accordance with Erciyes University Graduate Education and Teaching Institute Thesis Preparation and Writing Guide.

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Director of the Institute

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ANALYSIS OF ECONOMIC AND TECHNICAL EFFICIENCY OF SUNN PEST MANAGEMENT AND ITS IMPACT ON WHEAT PRODUCTIVITY IN IRAQ

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ABSTRACT

In this study, the technical and economic efficiency of some factors affecting the wheat farms in the central region of Iraq were measured. Estimating the size of these factors affecting production and achieving economic and technincal efficiency was done using the data envelope analysis method (DEA). Its aim was to determine the size of the losses in the areas where the least efficient sunn pest management systems were used, and the possibility of measuring the cost of wheat production and the revenue generated by farmers. Random multiple stratified sample were selected according to controlled and uncontrolled sunn pest farms in the provinces of Wasit and Diyala. The sample size was 146 farms. Data were collected from farmers by filling out questionnaire forms filled out by the researcher. Besides a total of 6 members of university staffs were surveyed. The results indicates that the uncontrolled farms were at low levels of return capacity (39%) or less, they represent 88% of the sample farmers operating under constant return to scale (CRS), the efficiency in variable return of scale (VRS) was 71% of the number of sample farms distributed over the last two categories (40-59%) and (39% and below). While the opposite is observed in the controlled farms, the numbers were concentrated in the return of scale over the last two categories first and second (80-99%) and (100%).

The results of farmer survey indicated that most farmers do not have sufficient education on the biology of sunn pest, how to control it and its chemical control. Beside, most of them do not know how to measure the success of chemical control, and few of them would like to get educated about Sunn pest. Farmers don't know about the side effect of chemical pesticides and the effects of chemical pesticides applied with airplane on the environment and human health. While 6.2% of farmers believe application with

ground equipment is more successful, 85.6% of farmers think that airplane application is more efficient.

In the university staff survey, 100% of the responders think that the management of the government against sunn pest is insufficient because of staff deficiency, insecticide shortcoming, delays in the application of control measures, and finally lack of biological control activities and centers in Iraq.

Keywords: Sunn pest, *Eurygaster integriceps*, economic efficiency, technincal efficiency, Iraq

SÜNE MÜCADELESİNİN EKONOMİK VE TEKNİK ETKİNLİĞİNİN ANALİZİ VE IRAK'TA BUĞDAY ÜRETİMİ ÜZERİNE ETKİSİ

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ÖZET

Bu çalışmada, Irak'ın merkez bölgesinde, buğday çiftliklerini etkileyen bazı faktörlerin teknik ve ekonomik etkinliği ölçülmüştür. Üretimi etkileyen ve ekonomik ve teknik etkinliğe ulaşmayı sağlayan bu faktörlerin boyutunun tahmin edilmesi, very zarf analizi yöntemi ile yapılmıştır. Çalışmanın amacı, en az etkin süne mücadelesi yapılan alanlardaki kaybın boyutunu ve buğday üretiminin maliyetini ve çiftçilerin gelirini ölçme imkanlarını belirlemekti. Süne mücadelesi yapılıp yapılmamasına göre, Wasit ve Diyala İllerinde tesadüfü çok katmanlı örnekler seçilmiştir. Örnek ölçüsü 146 çiftlik olmuş ve veriler çiftçilere, araştırmacılar tarafından doldurtturulan anket formlarından sağlanmıştır. Bunun yanında, 6 üniversite çalışanı da örneklenmiştir. Sonuçlar, mücadele yapılamayan çiftliklerin, dönüşüm kapasitesinin aşağılarında (%39 veya altı) yer aldığını göstermiştir. Örneklenen çiftliklerin %88'ini temsil eden bu grup, sabit dönüşüm skalasının altında yer almıştır. Bu grubun değişken dönüş skalasının etkinliği %71 olup, örnek çiftlikler son iki katogori olan %40-59 ve %39 ve altı gruplarında yer almıştır. Mücadele yapılan alanlarda ise, tersi gözlenmiş olup, çiftliklerin, dönüşüm skalasının üst iki grubunda (%80-99 ve %100) yer aldığı gözlenmiştir.

Çiftçi anketlerinin sonuçları, çiftçilerin çoğunun, sünenin biyolojisi, onunla nasıl mücadele yapıldığı ve kimyasal mücadelesi hakkında yeterince eğitimlerinin olmadığını göstermiştir. İlave olarak, çiftçilerin büyük çoğunluğu, kimyasal mücadelenin başarısının ölçümünü de bilmemekte ve bunların çok azı süne konusundaa eğitim almak istemektedir. Bu eğitimsizliğin doğal sonucu olarak, çiftçiler, kimyasalların yan etkilerini ve uçakla ilaçlamanın çevre ve insan sağlığına etkilerini bilmemektedir. Çiftçilerin %85.6'sı uçakla, %6.2'si yer aletleriyle ilaçlamanın daha etkili olduğunu düşünmektedir.

Üniversite personeli anketinde, katılımcıların %100'ü, Devletin süne mücadelesinin, elaman yetersizliği, insektisit azlığı, mücadeledeki gecikmeler ve Irak'ta biyolojik mücadele çalışmaları ve merkezlerinin olmamasından dolayı, yetersiz olduğuna inanmaktadır.

Anahtar Kelimeler: Süne, *Eurygaster integriceps,* ekonomik etkinlik, teknik etkinlik, Irak

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CHAPTER 1

INTRODUCTION

Wheat is one of the most important grain crops, the most widespread in the world and of strategic importance. It plays a major role in international politics and its lack is a threat to the sovereignty and food security of any country.

Wheat is the main food for more than two-thirds of the world. The cultivated area covers 225 million has and occupies the largest production area compared to the area of other food crops. China is ranked first in wheat production with a production of 117.4 million tons, 16.7% of the world production of 704.1 million tons. India comes second with 86.9 million tons, followed by the USA with 56.2 million tons. As for the Arab world, Egypt ranked first in terms of production with 8.4 million tons, followed by Syria with a production rate of 3.9 million tons [1].

Wheat is grown in Iraq in a wide range of environments from rainfed in northern part of Iraq and its production is heavily affected by the amount and distribution of rain during the growing season. Wheat is also cultivated in irrigated areas located in the central governorates on the Tigris and Euphrates basins. Irrigation water is available in its winter planting season. Wasit province is the first in the production of wheat, followed by Diyala province. Iraq's average annual production of wheat is 2.8 million tons [2].

This quantity is unpretentious compared to other countries in the world, and its production is often subject to fluctuation as a result of the negative impact of agricultural pests [3]. The crop has many pests and the sunn pest (*Eurygaster integricesps*) at the forefront of these pests, and cause loss of 70-90% of the cultivated land crop. Sometimes, the infection may leave large areas of wheat without harvesting [4].

The sunn pest attacks the grains, which are in the milky stage or at the dough stage, where the insect pits grains and absorb its liquid content, which leads to the the atrophy of grain and wrinkle content and reduce starch and protein content. This leads to a decrease in the yield and vitality of germination and low rates of extraction flour product of grain [5].

The sunn pest passes through winter and summer hibernation periods during its life cycle, and the date of the appearance of the sunn pest adults in the migratory fields differs from one place to another and from year to year depending on the temperature prevailing in those fields. The sunn pest begins to migrate from the sites of hibernation to the fields cultivated with wheat from mid-March to early April, when temperatures reach 17- 19°C [6].

The insect begins the stage of summer hibernation as it tuck with soil under the weeds and bushes to get rid of high temperatures. Summer migration began in late June and continued until the beginning of July and then moved from the areas of summer hibernation to winter hibernation areas in the last week of October and the first week of November [6].

The research derives its importance first from the importance of wheat as a key element in the family food basket in Iraq, contribution to many of the main food industries, and usage its fodder as livestock feed. It is an important source of agricultural income. The importance of the research is also to evaluate the performance of the management of the pest control systems that fascinating the crop and reduce the loss when the signs of infection appears in fields to avoid the injury to the critical economic level, which ensures the safety of production and avoid the income losses of farmers.

The study is supposed to encourage farmers to monitor the presence of the insect in the early time before injury, helps to increase the efficiency of the pest management and eliminate the damage and consequences of its negative presence on the yield.

The aim of this research is to determine the size of the losses in the areas where the least efficient pest control management systems were used, and the possibility of measuring the cost of wheat production and the revenue generated by farmers, in light of the less efficient control management systems to the more efficient control systems.

CHAPTER 2

GENERAL INFORMATION

2.1. Description and Life Cycle of Sunn Pest

The sunn pest, also known as the suni bug and the cereal bug, belongs to Family Scutelleridae in the Order Hempitera under the *Eurygaster* genus. There are 15 species species of this genus in the world. While *Eurygaster integriceps* Put., *E. maura* L. and *E. austriaca* Schrank are important pests in terms of their economic devastation to the crops in Romania, *E. integriceps* Put., *E. maura* L. and *E. austriaca* Schrank, *E. dilaticollis* Dohrn, *E. Hottentota* F., *E. Schreiberi* Mont, *E. Testudinaria* Geof. cause serious problems to ceareals in Turkey [7, 8]

Adults of *E. integriceps* are largish (about 11.5-13 mm long), rounded, with a long scutellum which covers the entire abdomen. The shield-like shape and extent of this scutellum makes these bugs look almost beetle-like and gives them their family name. They have a broad body with a length-to-width ratio of 1.56 [7]. There is a broad variation to their body coloration. For example, these insects can be a yellow-brown hue (in newly emerged adults), red, dark brown, or black in Northern Iraq alone. Lighter-shade variations of these bugs feature darker markings on their exterior. Most variations feature a white marking in the shape of an “M” along the base of their scutellum, but this can also appear are two black and white spots, as in the case of the *E. maura*. The only method of distinguishing the *E. integriceps* from the *E. maura* is through examining the different features of their sexual organs (i.e., the male aedeagus).



Figure 2.1. Sunn pest in field located at Wasit province

There is only a single generation yearly of the *E. integriceps*, which these insects survive for only a maximum of one year. Between June and October (the summer through autumn periods) along the Northern Hemisphere, the adult *E. integriceps* fly from their dwellings along the low-altitude cereal crops (mainly wheat) to higher altitudes atop mountains. They do this to overwinter under low shrubs during frigid temperatures. They have been observed as reaching altitudes of up to 2,000 m above sea level in some locations [9]. Atop these mountains, there are two stages for their over-wintering. The end of their first stage (aestivation) comes in the middle of October, which drives the insects to lower altitudes, escaping the harshest temperatures at the onset of their second stage in an overwintering process which lasts up to nine months for adult *E. integriceps* [10].

The dense forests atop mountains are unavailable in some regions (Baghdad, Syria, and Ukraine, for example), which causes the *E. integriceps* in these places to secure unique overwintering sites, such as in the soil near the fields [11], or weeds and garbage beneath available plants [12]. As such, the total population of the *E. integriceps* is dependent upon the local weather conditions and on the nearness of crops to woodlands, grasslands, and mountaintops, not upon their dispersal. These insects mate towards the

end of their overwintering, as the necessary temperature upwards of 13℃ [7]. Afterwards, they migrate back to the crop locations to fed from February until April [13].

In the time before the grains (and seeds) are developed, the adult insects will feed on wild grass. They can deposit eggs in a variety of ways: onto the host plant, within weeds near the crops, or on top of pebbles. During their life cycle (one year), females can lay nearly 200 eggs on wheat and around 185 eggs on barley [14]. These eggs hatch between late May and June at the period when the grains and seeds are developing, four to ten days after being laid [15]. When eggs are being hatched, the adults who have returned to the crops will begin to die off. The *E. integriceps* eggs are quite fragile and subject to breaking. The *E. integriceps* insects reach maturity after five nymphal instars, with the first four taking around four to seven days each, and the final instar taking 11 days. The complete maturity process from egg to full adult can occur at 35-37 days at the earliest, but could be delayed for up to 50 to 60 days based on the field conditions and the availability of food [9].



Figure 2.2. Sunn pest eggs in field located at Wasit province

Young instars have a diet comprised of stems and leaves and hide deep within plant canopies to avoid predators. The primary diet of older instars and adults is the developing grain. However, if the grains are fully mature before the completion of the *E. integriceps* maturity period, then both the adults and the nymphs can feed on the dry grains, as long as moisture can be found from dew and/or rain [15, 16].

The feeding persists until the young insects have built up enough fat reserves to last the over-wintering period. In such cases when the cereal crops are harvested before the insects have stored enough fat, then the insects will relocate to a nearby field for feeding until they can secure the necessary reserves [17]. When an outbreak of *E. integriceps* occurs, density figures are as many as 120 insects per square meter on crops [18], and 1,000 insects per square meter at the overwintering locations [9].

Sunn pests thrive at temperatures between –30°C and 45°C [14], dying when the temperature exceeds 49.5°C. When the temperatures become exceedingly hot, the *E. integriceps* find security within soil cracks or underneath leaves that pile at plant bases [16]. It is possible that the populations remain in the fields and not migrate for overwintering if the instars and young adults have not secured enough fat reserves to survive the season [11].

As mentioned, the adults have a lifespan of around a year, based on their environmental temperature. *E. integriceps* mortality rates can be impacted by this failure to migrate due to lack of fat reserves that cannot sustain the insect for overwintering [9]. Beyond migration habits, body fat percentages also impact the insects' fertility, which plays a role in species outbreaks [19]. Under optimal conditions, these outbreaks take place every five to eight years [20]. Such a condition would be if the grains and nymphs mature at the same time, which allows for most insects to secure their necessary fat reserves and overwinter until spring [21].

2.2. Hosts, Damage and Distribution of Sunn Pest

Common names for the insect include: Sune, sunn pest, sunne pest, sunni pest, suni pest, sunn bug, soun bug, soune bug, senn bug, sen pest, wheat shield bug, and noxious pentatomid. The *E. integriceps* predominantly attack grains, feeding on the leaves,

stems and grains [22]. They feed on wheat and barley crops, wild Gramineae weeds [23] millet, sunflowers, linen, and clover [24].

The insects can cause a complete destruction if they attack the kernel during its "milky" period, or damage can appear as shriveled if attacks take place during late-stage maturity. Destruction can be noticed by a black pinpoint on the grain which is covered by pale or discolored holes. These markings are caused by the insects' toxic saliva which is used to destroy the grain's gluten. Grain attacks can occur as either: lessened crop yield, weakened seed germination, or a lowered gluten index of the harvested grains. For the first type; grain yields are measured using the 1,000-grain weight, which can be reduced to between 78 and 92 percent after a sunn pest attack when compared to normal grains. Germination of attacked grain is also usually affected, only 88% germination being obtained where 14% of kernels are attacked [7, 24–31]

In the third type, grain damage; the gluten is weakened by enzymes, injected by the insect into grain to be able to feed on it, which can cause lesser elasticity. This will produce abnormal dough that doesn't knead as it should, due to soft and sticky gluten. Bread made from this dough will be of lower quality which can appear crumbly, smaller, have lower porosity, and can be difficult to digest. Experts claim that only two to three percent of grains need to be affected for it to become unusable for baking [33]. Hard wheats are more susceptible to this than soft wheats [34]. The critical threshold is closer to three to five percent depending upon wheat variety [34, 35] and grain damage in excess of 5% can still produce acceptable bread depending on the acidification of the water used to make the dough. Still, the serious impact on the dough is noticeable in that it becomes impossible to roll the dough and form loaves based on the lowered elasticity [37]. The major damage wrecked by the pests comes from feeding of older nymphs and adults, with seed weights lessened by 5mg than normal grains [37–45].

E. integriceps are primarily distributed between 25 and 55 (N) latitude and between 20" and 80" (E) longitude in the northern hemisphere [46, 47]. That said, they also extend into the west and the east. For example, they are found in the Middle Eastern countries of Turkey, Iran, Iraq, Israel, Syria, and Lebanon [10, 48–50]. In eastern Europe it is found in Croatia, Serbia and Montenegro of the former Yugoslavia, Greece, Bulgaria, Romania, and the Ukraine. In western Asia, it is found in the Russian Federation of the

CIS, Kazakhstan, Uzbekistan, Kyrgystan, Tajikistan, Afghanistan and Pakistan [22]. *E. maura* is dispersed throughout all of north Africa and western Asia, except in the north and south [48]. *E. austriaca* is spread throughout southern Europe, north Africa, Turkey, and Iran. These sunn pests have had a significant economic impact over the last 70 years, being spread across over 15 million has of land in the aforementioned regions [47].

2.3. Cultural Control of Sunn Pest

Because of their significant impact, controlling these pests has become a serious agricultural concern. Cultural control methods are now being used on a major scale, including planting crops earlier and planning cereals with an earlier maturity period that allow grains to be harvested before the nymphs arise [52]. Another practice involves the elimination of weeds from fields using herbicides at all stages of crop development (before and during) because the green weeds are necessary in allowing the pests access to the dry grains [53] or the weeds themselves can serve as hosts for the pests. A method that has proven effective in several countries is harvesting crops as quickly as possible and not leaving ripened fields unharvested using the two-stage harvesting method (taking only five to seven days) [46]. Additionally, research carried out by the International Center for Agricultural Research in the Dry Areas (ICARDA) has focused on different varieties of wheat that have higher resistance to the sunn pests [53, 54]. These include early-maturing crops that disallow the insects to store enough fat reserves for future outbreaks.

Research in Iran has discovered that hard wheats have proven more resistant than the soft wheats [56]. The resistant wheats retain high levels of gluten even after an attack that causes 15 to 20 percent of damages from the sunn pests [56, 57]. Undesirable wheats feature more spike density, height, a longer awn, and later maturity periods, leaving them susceptible to sunn pest attacks [49, 55, 58, 59]. A relationship has been drawn between the booting growth stage and the severity of damage received after attack, with earlier varieties being more resistant to harm [61].

On the contrary, a study in Turkey revealed no changes in the density of sunn pest nymphs and grain yield when comparing early, mid-season, and late-season wheat types [59].

The effect of different planting methods of early, mid-season and late wheat varieties did not result in changes in sunn pest nymphal density and grain yield in Turkey [61]. That said, the study also determined that the durum wheats have a significantly higher resistance quality regarding damage caused by the pests and their overall density. As such, this research provides invaluable data pertaining to potential gene sources used in wheat breeding to build resistant varieties.

2.4. Biological Control of Sunn Pest

Although most control efforts rely on chemical and cultural methods, significant research has been undertaken in the recent years into using biological control agents to combat the sunn pest, particularly using predators, parasitoids, and pathogens [63, 64]. A research has reported [64] a variety of predatory spiders that feed on sunn pest belonging to 14 families. Another study [4] outlined the following viable predators: *Chrysoperla carnea* Steph, *Calosom maderae*, *Diomahda fisheri* Fald, *Cataglyphis bicolor* F.

A Russian study [65] used 28 predators along 13 genera of the Carabidae family to feed on sunn pests at various stages in wheat fields recorded an 11.3 percent reduction in the insect's density.

An important biological control agent of *E. integriceps* has been identified as the hymenopteran egg parasitoid in the genus *Trissolcus* receiving noteworthy acclaim for its effectiveness in dealing with an outbreak [65–70]. Through experimentation using the *T. grandis* on Iranian wheat fields, 90 percent of sunn pest eggs were parasitized successfully.

A study conducted in Turkey [72] demonstrated the efficacy of the *T. semistraitus* parasite on the insect's eggs. They reported 11,640 eggs successfully laid into the pests at a temperature of 32°C. The successfulness of parasitism using *T. semistraitus* were further recorded at 28.5 to 50 percent in Syria [73] and 69.3 percent in Turkey [74]. Other successful parasitoid species that have been used against the sunn pest eggs include *T. rufiventris* Mayr, *T. vassilievi* Mayr *and T. festivae* (Victorov) [75–77]. Considering the *Trissolcus* spp. as a parasitic agent involves determining many outside factors, including exposure time, host age, and host to parasitoid ratio. A study

conducted in Turkey further revealed a strong correlation between the density of overwintered adults of the sunn pest and the effectiveness of parasitism. The spread of these pests were most successful when nymph populations at a ratio at or below 1.5 adults/m^2 [78, 79].

The parasitism rate of *T. grandis* is density-dependent for a minimum 6 sunn pest adults/m2 exposed to a minimum 2 *T. grandis*/m2. The parasitoids of greatest importance were found in the family Scelionidae within the hymenopteran superfamily Proctotrupoidea [80]. When comparing various studies into the effectiveness of parasitoids in controlling sunn pest outbreaks, the family Scelionidae (within the hymenopteran superfamily Proctotrupoidea) has proven most effective. This small insect species is known for parasitizing spider and insect eggs, with the females known by their linking to adult females of the host species until laying eggs before leaving to attack the host's eggs. This described process is known as "phoresy" and is also found in the Eucharitidae of the chalcid family.

A study [81] determined that the *Trissolcus grandis* Thous parasitoid is the most common in fields, with a prevalence reaching 85 percent in modern times. It was further reported [48] that *T. grandis* and *Telenomus chluropus* were the two most active parasites on the sunn pest eggs in Serbia and Montenegro.

Microbial control agents have also gained recognition for their usage against sunn pest outbreaks because of the low environmental impact. They provide advantages in combating pests by their complex action modes [82]. They can be effective during diapause, when other agents are ineffective [51, 84]. As example of this is how entomopathogenic fungi (*Beauveria bassiana*) and the *Bacillus thuringiensis* microorganism have developed strategies to counteract the host defense systems using secondary metabolites that breach the cuticle and colonize the hemocoel [84]. Using these two mentioned control agents against *E. integriceps* has been popular for several years now [85]. A research has been recorded throughout the Middle East [63, 86] outlining their effectiveness against sunn pest adults. Similar research in Iraq has found the effectiveness using *Bacillus* spp. [87].

Beyond the egg parasitoids, some studies have revolved around using alternative natural enemies to the sunn pests as a control method, including a Turkish study into the

effectiveness of mermithid nematode, *Hexamermis eurygasteri* n. sp. on sunn pest adults. The successful parasitism rates were recorded at 20 percent and 16 percent for females and 31.6 percent and 7.1 percent for males regarding the *E. maura* and *E. integriceps*, respectively [88, 89]. A study conducted in Pakistan [90] recorded that many sunn pests die in their overwintering sites when infected by nematode species.

Using nematodes have proven effective against a great deal of pests that cause economic strains [91, 96] over their 25-year usage within the crop and forest industries [91]. Although there has been research conducted into their effectiveness against pests, there is stilll limited knowledge regarding their natural host range and how they can limit insect infestations [93].

2.5. Chemical Control of the Sunn Pest

Chemical pesticides are perhaps the most commonly used control agent against sunn pests because of their ease of use and understood efficiency. Every year, more than 10 million ha are sprayed with these agents across the Near East and West Asia, costing around $150 million [99–101]. In Iran, the most common control pesticides used against the sunn pest include deltamethrin, fenitrothion, trichlorfon, and lambda cyhalothrin [97]. The overall toxicity and effectiveness of these insecticides changes depending on the different sunn pest species and the stage of life when they are treated. As an example, there has been no recorded resistance evidence of the *E. integriceps* against alpha cypermethrin and fenitrothion [98], whilst there has been resistance recorded in Turkey of these agents against *E. maura* [99].

In Turkey Chemical control activities are begun with overwintering site survey which is made to estimate next year's sunn pest population and find out the migration time in the fall and spring on same sites every year. A 1/4 m^2 (25 x 25 cm) frame is used or brushes are cut to count sunn pest. When the 90% of the overwintering adults of sunn pest left the overwintering sites to migrate to wheat fields, a rough survey is done to find out the area infested by sunn pest. It's done just by observation. Then density evaluation survey is started to find the density of sunn pest populations in the field and identify the area where the chemical control will be applied. For this survey, the same frames are used. The frame is tossed in the field randomly and every thing (plants,

weeds, soil) in it is carefully checked. One third of fields in a region need to be checked.

In the areas where the overwintering adult density is ≥ 0.8 / m^2, the units are watched closely. The economic threshold (ET) is 10 nymphs / m^2. The fields reached to ET are sprayed against sunn pest at 2^{nd}-3^{rd} nymphal stages with one of insecticides containing cypermethrin, deltametrin, alpha cypermethrin and lambda cyhalothrin or similar one. If the parasitation rates are 40, 50, 70, and >70% in the units where overwintering adult densities are 0.8, 1.0, 1.5, and 2.0 / m2, respectively, the units are not sprayed. These unites are watched carefully and the spray is made on 4-5^{th} nymphal stages if necessary to protect parasitoids. Only nymphal stages are sprayed to protect parasitoids in Turkey, whilst spray is made against overwintering adults if the density reaches up to 3 overwintering adults / m^2 as well as against the nymphal stages.

The ET for sunn pest is defined as a population density of nymphs or nymph plus new generation adults or overwintring adults per square meter which cause kernel damage that ruins the baking quality of dough. There are many studies to define ET for the sunn pest to decide pesticide applications. [100] suggested to apply insecticide against the sunn pest when nymphs were over 20 per square meter if wheat plants (spikes) were 600-700 per square meter. [101] stated that ET should be 10 nymphs/m² against third instars at low population density and 15 nymphs/m² against first-second instars at high population density. [102] in Kazakistan and [103] in Greece suggested that ET for *E. integriceps* could be 10 nymphs per meter square against second instars, which was practical ET applied most parts of Turkey. [104] in Ukraine stated that spraying against only overwintered sunn pest adults was not enough and there was a need of a second spraying against second to third instars at the beginning of kernel formation period at the density of 4-6 nymphs per square meter.

In a 5 year study conducted in Romania, [105] mentioned that the ET for *Eurygaster* and *Aelia* species were 10 nymphs per square meter. The yield loss caused by 2-3 over wintering aduls (OWAs) per square meter and their nymphs could be tolerated if plant number is between 400-500 per square meter. Whereas [106] in the same country stated that the ET would be 5 nymphs per square meter for wheat for consumption purposes as bread and 3 nymphs at seed production fields and it varies depending on growth stage of

wheat, climatic conditions, usage purpose of yield, and pest density. On the other hand, [107] emphasized that 2 OWAs per square meter could cause important damage and chemical applications were needed at the density of 2 fourth-fifth instars plus new-generation adults. [108] found out that 7 nymphs plus new generation adults (NGAs) per square meter in Iran and 10 nymphs plus NGAs per square meter in Turkey did not reduce the baking quality of wheat dough. [109] expressed that ET for the Sunn Pest was 5-10 nymphs at the flowering stage, 5-6 nymphs after flowering in Syria.

In Turkey, there are considerable researches on ET for the sunn pest. [110, 111] stated that sprays applications for the sunn pest could be directed to mainly first-third instars. The fields where the overwintered adult density is over 0.8 per square meter should be kept under check and sprays should be started for first-third instars and continued for nymph plus NGAs if the density exceeds 10 nymphs or nymph plus new-generation adults. [112] indicated that the ET for the sunn pest was 8.1 and 9.2 nymphs for bread and durum wheat varieties, respectively in South Eastern Turkey. [113] found out that the tolerance limit for kernel damage was 3.5% against *Eurygaster maura* in a research conducted Central Anatolian Region of Turkey in 1997-2008. The ET was 6-8 nymphs, which could be changed depending on spike number per square meter and kernel number each spike.

The ET determined in Turkey and out of Turkey varies greatly by ranging from 2 to 20 nymphs per square meter. This difference depends on socio-economic needs of the country, usage purpose of wheat, phenological stage of wheat, growth stage of the sunn pest, and tolerance limit for kernel damage in the country.

2.6. The Concept of Economic Efficiency

Economic Efficiency

The use of production resources in such a way as to achieve the largest amount of production at the lowest costs, Economic efficiency is achieved through the optimal use of productive resources under alternative resources available. Economic efficiency is defined in terms of inputs as the farm that has the capacity to reduce input to reach the specified production, While economic efficiency in terms of outputs is defined as those

that have the ability to increase the quantities of production by optimal use of the same amount of inputs [114].

$$EE = TE * AE$$

Allocative efficiency

This concept represents the degree to which the marginal benefits is almost equal to the marginal costs. Hence, at the optimal level of efficiency, the marginal cost of the last unit is perfectly equal to the marginal benefit that consumers derive from the good or the service [115].

Technical efficiency

Is the ability of the farm to achieve the greatest output from the use of the optimal mix of available inputs. is also known that the farm has the capacity to convert inputs into material outputs, as it is the measure of the success of the farm in the maximum output of the quantity of inputs available. The improvement of the economic level of the plant is the goal of the agricultural systems mechanism. Developing countries suffer from misuse and disposal of available resources [116].

$$\mathrm{TE} = \frac{\mathrm{CRS}}{VRS}$$

Technical efficiency is between (0-1) and inversely correlated with the level of technical inefficiency. The farm is technically efficient when the technical efficiency is equal to one, but if it is less than the right one, the farm can reduce the input ratio [117].

Constant return to scale

Production increases with the addition of a new quantity of variable production factors, which means increasing production by the same amount, indicating a constant proportion of the production components and the volume of output in the production process [118].

Variable return to scale

If production increases by more inputs, revenue increases. When adding one additional unit of production, the total output rate exceeds the rate of increase. The increase in production volume is faster than the increase in the productive component used.

If production increases by more inputs, revenue increases. When adding one additional unit of production, the total output rate exceeds the rate of increase. The increase in production volume is faster than the increase in the productive elements used [118].

Return to scale

Is the optimal utilization of resources as it measures the ability of the farm to achieve economic savings as a result of the exploitation of its expansion potential, the state of the production process before the optimal level of production where the relative change in output is greater than the relative change in its components [118].

2.7. Methods of Estimating and Measuring the Economic Efficiency

The first DEA model, proposed by Charnes, Cooper and Rhodes (1978) named DEA-CCR in homage to their authors. The basics of data envelopment analysis DEA is specially designed technique for measuring of the efficiency of complex entities with diverse inputs and outputs. Increasingly it is being used for evaluation and improvement the operation of numerous business entities, and its use is expanded on evaluation the efficiency of schools, hospitals, bank branches, production facilities, etc. The analysis provides results based on which we can determine how much are some units inefficient compared to efficient units. In this way, it is possible to determine also how much is necessary to reduce the input and/or to increase the output of unit to become efficient. All of these units are called DMU (Decision Making Unit). For each inefficient DMU, DEA identifies a set of corresponding efficient units that can be used as indicators for improvement [119].

CHAPTER 3

MATERIALS AND METHODS

3.1. Initial data

A random sample of wheat farms was collected in the provinces of Wasit and Diyala in Central Iraq. The sample size was 146 farms from the total farmers in the two governorates. There statistivally reasons for the selection of samples and one of these reasons is that the sample must represent the community by 5% in order to be acceptable statistically. Half of the sample included wheat farms that were treated with pesticides by the airborne spray and the other half were not reached for control. Data were collected from farmers by questionnaire forms filled out by the interviewing researcher face-to-face.



Figure 3.1. Geographical distribution of the central region of Iraq

3.2. Secondary data

The secondary data were obtained from the records of the Central Agency for Agricultural Statistics in the Ministry of Planning, the Directorate of Plant Protection of the Ministry of Agriculture, and Farmers' Union. Interviews were conducted with the staff specialized in the control of the sunn pest and data on the sunn pest was obtained.

3.3. Statistical Analyses

The Data Envelopment Analysis (DEA) method was used to estimate the efficiency of the technical output and economic efficiency of wheat farms in the research sample. Two methods were used in the analysis of this type of data, The first trend is the use of the DEA method, according to the change in return of capacity, and the second direction according to the stability of return of capacity, allowing for the assessment of technical efficiency, and capacitance efficiency, by inputs under the variables of the production function, either the use of the output side was not investigated because it is not appropriate to the conditions of the reality of agricultural work. Price efficiency and economic efficiency were also estimated according to cost function variables.

A program was used (DEA) In the analysis as it provides detailed information on the use of productive resources and the optimal mix of them and the possibility of measuring the efficiency of each farm, and identify the sources of inefficiency. By adopting the method of estimating the efficiency of different farms through the creation of an envelope containing the data, which is called the data envelope to the fact that productive units (productive farms) with administrative and organizational efficiency are encapsulated to the less efficient or inefficient productive units.

To identify the effects of this insect by comparing the farms were managed in a timely manner and the possibilities to eliminate them, and farms stumbling control means in the performance of its role in maintaining the resources of farmers, which are a key goal to maximize their profits and revenues, were the sunn pest exceed the critical economic limits in their farms and destroy their farms and their production, which caused waste in the economic resources that are supposed to be perfect exploited especially the rare ones.

As for the data on the sunn pest, data were collected using questionnaire. Some tables were analyzed according to Likert Scale using SPSS statistical software.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Technical Efficiency Measurement Results

This study includes the estimation of the results of the technical efficiency (TE) of the farmers of the research sample for the growing season 2017- 2018 using DEA method. The technical efficiency model of the DEA was estimated. The explanatory variables of the production function included the amount of compound fertilizer (kg), the amount of urea fertilizer (kg), the number of machinery hours worked (hours), number of hours of human work (man hours). The constant return to scale (CRS) and variable return of scale (VRS), the technical efficiency index (TEI) is limited to zero and one. If they are equal to one, the farm is produced on the optimal potential production curve, if less than one, the farm is produced under the optimal production curve. The results of the return of scale are used after dividing the efficiency with the constant return to scale (CRS) with the variable return of scale (VRS) using the statistical program DEA.

4.1.1. Uncontrolled farm

The level of technical efficiency varies according to the hypothesis of variable return of the scale of the wheat farms for the research sample between a minimum of 0.1 and a higher level of 1)with an average of 0.524, This indicates that farmers have the opportunity to increase production by 0.476 without increasing the resources used. In order to determine which farms achieved the highest technical efficiency in light of the VRS, the sample was divided into five categories as shown in Table 4.1. The category 100% was restricted to 8 farms and accounted for 11% of the sample farms, the second category confined between 80 - 99% It included 5 farms and accounted for 7% of the sample farms, and their average efficiency is 0.846. This means that these farms in order to be efficient should increase their production by 0.154. The return of scale,

which indicates the rate of resource utilization, has achieved one farm with an average of 0.815, while the category 60 - 79% also achieved 8 efficiency farms, which accounted for (11%) of the sample farms with average efficiency 0.724. This means that farms to be efficient must increase their production by 0.276. In light of the of scale return, 17 farms 23% of the total sample farms with average efficiency of 0.682 were achieved. Farmers in the second and third categories were keen to provide production inputs to achieve production that matched the level of the equipment but did not show sufficient interest in light of the constant return to scale (CRS). The category of 40 - 59% has achieved 29 farm and accounted for 40% of the sample farms and their average efficiency 0.478. In order to be efficient, the quantity of their production should be increased by 0.522. As for the VRS, 23 farms accounted for 32% of the sample farms of the number of farms sample has an average efficiency 0.509. The category of 39% and below has reached the number of farms achieved efficiency in the light of VRS 23 farms accounted for 31% of the number of farmers sample with the average efficiency 0.277, This means that farms to be efficient should increase their production by 0.723. The scale efficiency, achieved 32 farms, which accounted for 44% of the sample farms with the average efficiency 0.233. It is noted that the low levels of efficiency confined to the last two categories were formed with the CRS 99% of the number of farms in the sample, which reflects the great waste and loss. With a VRS, efficiency was low and included 71% of the number of sample farms. The scale efficiency for all levels and indicators indicates the possibility of increasing efficiency.

Table 4.1. The number of uncontrolled farms according to levels of technical efficiency

Efficiency level %	**Number of farms**					
	Efficiency in CRS[1]	**%Sample**	**Efficiency in VRS[2]**	**%Sample**	**Return of the scale**	**Sample %**
100	**0**	**%0**	**8**	**%11**	**0**	**%0**
80 – 99	**0**	**%0**	**5**	**%7**	**1**	**%1**
60 – 79	**1**	**%1**	**8**	**%11**	**17**	**%23**
40 – 59	**8**	**%11**	**29**	**%40**	**23**	**%32**
< 39	**64**	**%88**	**23**	**%31**	**32**	**%44**
Total	**73**	**%100**	**73**	**%100**	**73**	**%100**

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.
[1] Constant return to scale
[2] Variable return to scale

4.1.2. Controlled farms

The level of technical efficiency varies according to the effect variable return of the scale of the wheat farms for the research sample between a minimum of 0.563 and a higher level of 1 with an average of 0.758. This indicates that farmers have the opportunity to increase production by 0.242 without increasing the resources used. In order to determine which farms achieved the highest technical efficiency, the sample was divided into five categories as shown in Table 4.2. which when reviewed shows that efficiency under category 100% achieved 4 efficiency farms and accounted for 5% of the number of sample farms either under the return of scale, which refers to the proportion of exploitation of resources has achieved only two farms efficiency accounted for 3% of the number of farms sample, while the number of farms that have been limited efficiency 80 - 99% has achieved 16 farms with 22% of the sample farms and their average efficiency was 0.886 The number of farms achieved for the return of scale was 58 farms representing 79% of the sample farms and their average efficiency 0.917, The third category 60 - 79% achieved 47 efficiency farm constituted 65% of the sample farms and the average efficiency 0.717, while the number of farms achieved the return of the scale 13 farms, in this category, the sample farms were formed 18% with average efficiency of 0.729. The category (40-59%) achieved 6 efficiency farms constituted 8% with average efficiency of 0.576. Returning to the results of the analysis of technical efficiency and in light of the VRS, we find that all farms are working in the stage of revenues of increasing of scale and this means that the increase in the production resources result in an increase in production exceeding the increase achieved by the production resources that preceded it, The output requires a lower increase in the input in output.

Table 4.2. The number of controlled farms according to levels of technical efficiency

Efficiency level %	Number of farms					
	Efficiency in CRS[1]	% Sample	Efficiency in VRS[2]	%Sample	Return of the scale	Sample %
100	2	3%	4	5%	2	3%
80 – 99	8	10%	16	22%	58	79%
60 – 79	43	60%	47	65%	13	18%
40 – 59	19	26%	6	8%	0	0%
< 39	1	1%	0	0%	0	0%
Total	73	100%	73	100%	73	100%

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

4.2. Estimating the Amount of Resources Achieved For Technincal Efficiency

To estimate the amount of resources achieved for the technical efficiency of the sample farms of the wheat production identified by the resources the amount of phosphate fertilizer (DAP fertilizer) kg and the amount of nitrogen fertilizers (urea fertilizer) kg and the number of human working hours (man hour) and the number of hours of machinery work (hour), and depending on the method of Data Envelop Analysis (DEA) according to the function of production and resources mentioned. It was determined the size of resources achieved for technical efficiency, including the calculation of surplus or deficit compared to the actual resources used. Resources actually used - Amount of resources - to achieve technical efficiency and then calculate the amount of surplus or deficit of the actual quantity used, and calculated the productivity achieved for technical efficiency.

4.2.1. Compound fertilizers (DAP)

4.2.1.1. Uncontrolled farms

Eight farms achieved the full technical efficiency 100% formed 11% of the number of sample farms did not receive any waste or increase in the resources used. This is the optimal case Table 4.3. The number of farms that achieved efficiency within the category 80-99%, are 5 farms accounted for 7% of the number of farms sample with average efficiency of 0.807 and the average deficit 13.077 kg / ha and estimated the average value of waste 9.58 USD per ha. The farms that achieved efficiency within the category 60 - 79% were 8 farms accounted for 11% of the sample farms with average efficiency of 0.484 and the average deficit (33.120) kg / ha and the average waste value 25 USD per ha. The farms that achieved efficiency within the category 40 - 59% have reached 23 farms accounted for 40% of the sample farms and their average efficiency 0.478 and the average deficit 83.051 kg / ha The average value of the waste was 60.41 USD per ha. While the farms that achieved efficiency within the category 39% and below were 23 farms that accounted for 32% of the sample farmers and their average efficiency was 0.277, and the average deficit 126.556 kg / ha and estimated the average value of waste 92.08 USD per ha. The average deficit of this resource 87 kg / ha and the average amount of waste 63.36 USD per ha.

Table 4.3. Average waste of the compound fertilizer for samples farms for uncontrolled farms

Efficiency level %	Number of farms	Sample %	average deficit kg / ha	Average waste USD / ha
100	**8**	**%11**	**0**	**0**
80 – 99	**5**	**%7**	**13.077**	**9.58**
60 – 79	**8**	**%11**	**33.120**	**25**
40 – 59	**29**	**%40**	**83.051**	**60.41**
< 39	**23**	**%32**	**126.556**	**92.08**
Total	**73**	**%100**	**87**	**63.36**

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

4.2.1.2. Controlled farms

Four farms achieved full efficiency 100%, formed 6% of the number of farms sample and did not get any waste or increase in resources used and this is the best case Table 4.4.. while the farms that have been limited efficiency 80 - 99% has achieved 16 farm efficiency Within this category, contribute to 22% of the sample farms were formed with average efficiency of 0.888. The average deficit was 17.288 kg / ha. The average value of waste is estimated at 12.66 USD per ha. The farms, which have efficiency between 60 - 79% have reached 47 farm formed 64% of the sample farms and their average efficiency 0.717. The average deficit 46.245 kg / ha and estimated the average value of waste 33.75 USD per ha. While the farms whose efficiency was limited between 40-59% were 6 farms accounted for 8% of the sample farms and the average efficiency 0.576 and the average deficit 76.504 Kg / ha and the average value of waste 55.83 USD per ha. The average deficit of this resource 42.161 kg / ha and the average value of waste 30.77 USD per ha.

Table 4.4. Average waste of the compound fertilizer for samples farms for controlled farms

Efficiency level %	Number of farms	Sample %	average deficit kg / ha	Average waste USD / ha
100	**4**	**6**	**0**	**0**
80 – 99	**16**	**22**	**17.288**	**12.66**
60 – 79	**47**	**64**	**46.245**	**33.75**
40 – 59	**6**	**8**	**76.504**	**55.83**
< 39	**0**	**0**	**0**	**0**
Total	**73**	**100**	**42.161**	**30.69**

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

4.2.2. Nitrogen fertilizers (Urea)

4.2.2.1. Uncontrolled farms

Eight farms achieved the full technical efficiency 100%, which accounted for 11% of the number of farms in the sample and did not get any waste or increase in the resources used and this is the optimal situation Table 4.5. while the farms that were limited efficiency 80 - 99%, were 5 farms and accounted for 7% of the sample farms, with average efficiency of 0.846, and the average deficit was 24,352 kg / ha, and average value of the waste is estimated at 16.66 USD per ha. Whereas, The farms that were limited their efficiency between 60 - 79% were 8 farms accounted for 11% of the number of farms sample with average efficiency of 0.724, and the average deficit was 38.530 kg / ha. The average value of waste is estimated at 26.66 USD per ha. While the farms that were limited their efficiency between 40 and 59 % were 29 farms which accounted for 40% of the sample farms, with an average of efficiency of 0.478. The average deficit was 73.033 kg / ha and was estimated at the average value of waste 50 USD per ha, while the farms that have achieved efficiency within the category 39% and below has reached 23 farms accounted for 32% of the number of farmers sample and the average efficiency 0.277, the average deficit was 134 kg / ha, and the average value of waste 92.08 USD per ha. The average deficit of this resource 86.507 kg / ha and the average value of waste 59.54 USD per ha.

Table 4.5. Average waste of the nitrogen fertilizer for samples farms for uncontrolled farms

Efficiency level %	Number of farms	Sample %	average deficit kg / ha	Average waste USD / ha
100	**8**	**%11**	**0**	**0**
80 – 99	**5**	**%7**	**24.352**	**16.66**
60 – 79	**8**	**%11**	**38.530**	**26.48**
40 – 59	**29**	**%40**	**73.033**	**50.21**
< 39	**23**	**%32**	**134**	**92.12**
Total	**73**	**% 100**	**86.507**	**59.54**

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

4.2.2.2. Controlled farms

Four farms achieved the full technical efficiency 100%, accounted for 6% of the sample farms , and there was no waste or increase in the resources used. This is the optimal case Table 4.6. The number of farms that were efficiency limited to 80-99% were 16 farms accounted for 22% of the sample farms with an average efficiency of 0.888 and the amount of deficit was 21.158 kg / ha and the estimated value of waste 14.58 USD per ha. The farms, which efficiency were limited between 60 - 79%, amounted to 47 farms accounted for 64% of the number of farms sample with average efficiency of 0.717, and the amount of deficit of 54.568 kg / ha and the average value of waste 37.50 USD per ha. The farms with efficiency limited to 40 - 59% were 6 farms, which accounted for 8% of the number of farms sample, and the average efficiency of 0.576. The average deficit was 80.293 kg / ha and the average value of waste is estimated at 55 USD per ha. The average deficit of this resource 49.057 kg / ha is estimated to mean the average waste value 33.44 USD per ha.

Table 4.6. Average waste of the nitrogen fertilizer for samples farms for controlled farms

Efficiency level %	Number of farms	Sample %	average deficit kg / ha	Average waste USD / ha
100	**4**	**6**	**0**	**0**
80 – 99	**16**	**22**	**21.158**	**14.54**
60 – 79	**47**	**64**	**54.568**	**37.51**
40 – 59	**6**	**8**	**80.293**	**20.13**
< 39	**0**	**0**	**0**	**0**
Total	**73**	**100**	**49.057**	**33.44**

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

4.2.3. The number of machinery work hours

4.2.3.1. Uncontrolled farms

Eight farms achieved the full technical efficiency 100% accounted for 8% of the sample farms, There has been no waste or increase in resources used, this is the optimal case Table 4.7. The farms that their efficiency were limited to 80-99% were 7 farms accounted for 7% of the total number of sampled farms with an average efficiency of

0.864, and an average of 9.80 hours per ha. The average value of waste is estimated at 40.83 USD per ha. While the farms with the of efficiency of 60-79% reached 8 farms, which accounted for 11% of the sample farms with average efficiency of 0.724 and the average deficit of 6.34 hour/ ha. The average value of waste 26.41 USD per ha. The farms with efficiency of 40-59% were 29 farms accounted for 40% of the count of the sample farms and the average efficiency 0.478, and the average deficit 12.83 hours / ha and estimated average waste 53.33 USD per ha. The farms that achieved efficiency within the category 39% and below reached 23 farms accounted for 32% of the sample farms and the average efficiency of 0.277 and the average deficit 8.88 hours / ha and estimated average waste value of waste 37.08 USD per ha. The average deficit of this resource 10.40 hours / ha and the average value of waste 43.33 USD per ha.

Table 4.7. Average waste of the number of machinery work hours for samples farms for uncontrolled farms

Efficiency level %	Number of farms	Sample %	average deficit hr / ha	Average waste USD / ha
100	**8**	**11**	**0**	**0**
80 – 99	**5**	**7**	**9.80**	**40.83**
60 – 79	**8**	**11**	**6.34**	**26.41**
40 – 59	**29**	**40**	**12.83**	**53.45**
< 39	**23**	**32**	**8.88**	**37**
Total	**73**	**100**	**10.40**	**43.33**

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

4.2.3.2. Controlled farms

Four farms achieved the full technical efficiency 100%, accounted for 6% of the sample farms, and there was no waste or increase in the resources used Table 4.8. This is the optimal case. The number of farms that their efficiency were between 80-99% were 16 farms accounted for 22% of the sample farms with average efficiency of 0.888, and the average deficit 7.20 hours / ha and estimated the average value of waste 30 USD per ha. The farms, which had a efficiency of 60-79% reached 47 farms, which accounted for 64% of the number of farms sample with average efficiency of 0.717 and the average deficit 16 hours / ha and the average value of waste is estimated at 66.66 USD. The number of farms that their efficiency were between 40-59% were 6 farms accounted for

8% of the sample farms with average efficiency of 0.576, and the average deficit 31.115 hours / ha and estimated the average value of waste 60.73 USD per ha. The average deficit for this resource was 15,273 hr / ha and the average value of waste is estimated at 59.04 USD per ha.

Table 4.8. Average waste of the number of machinery work hours for samples farms for controlled farms

Efficiency level %	Number of farms	Sample %	average deficit hr / ha	Average waste USD / ha
100	**4**	**6**	**0**	**0**
80 – 99	**16**	**22**	**7.20**	**30**
60 – 79	**47**	**64**	**16**	**66.66**
40 – 59	**6**	**8**	**31.115**	**96.25**
< 39	**0**	**0**	**0**	**0**
Total	**73**	**100**	**15.273**	**59.07**

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

4.2.4. The number of human work hours

4.2.4.1. Uncontrolled farms

Eight farms achieved the full technical efficiency 100%, accounted for 11% of the sample farms, and there was no waste or increase in the resources used This is the optimal case Table 4.9. The number of farms that their efficiency were between 80-99% were 5 farms accounted for 7% of the sample farms with average efficiency of 0.846, and the average deficit 3.49 hours / ha and estimated the average value of waste 7.50 USD per ha. The farms, which had a efficiency of 60-79% reached 8 farms, which accounted for 11% of the number of farms sample with average efficiency of 0.724 and the average deficit 8.35 hours / ha and the average value of waste is estimated at 17.50 USD. The number of farms that their efficiency were between 40-59% were 29 farms accounted for 40% of the sample farms with average efficiency of 0.478, and the average deficit 15 hours / ha and estimated the average value of waste 31.25 USD per ha. The farms that achieved efficiency within the category 39% and below were 23 farms accounted for 32% of the sample farms and the average efficiency 0.277 and the average deficit 31.25 hr / ha and estimated the average value of waste 65 USD. The average deficit for this resource was 19,085 hr / ha and the average value of waste is estimated at 39.67 USD per ha.

Table 4.9. Average waste of the number of human work hours for samples farms for uncontrolled farms

Efficiency level %	Number of farms	Sample %	average deficit hr / ha	Average waste USD / ha
100	8	11	0	0
80 – 99	5	7	3.49	7.50
60 – 79	8	11	8.35	17.50
40 – 59	29	40	15	31.25
< 39	23	32	31.36	65
Total	73	100	19.085	39.67

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

4.2.4.2. Controlled farms

Four farms achieved the full technical efficiency 100%, accounted for 6% of the sample farms, and there was no waste or increase in the resources used This is the optimal case Table 4.10. The number of farms that their efficiency were between 80-99% were 16 farms accounted for 22% of the sample farms with average efficiency of 0.888, and the average deficit 1.40 hours / ha and estimated the average value of waste 2.91 USD per ha. The farms, which had a efficiency of 60-79% reached 47 farms, which accounted for 64% of the number of farms sample with average efficiency of 0.717 and the average deficit 4.44 hours / ha and the average value of waste is estimated at 9.160 USD per ha. The number of farms that their efficiency were between 40-59% were 6 farms accounted for 8% of the sample farms with average efficiency of 0.478, and the average deficit 7.49 hours / ha and estimated the average value of waste 15.625 USD per ha. The average deficit for this resource was 4 hr / ha and the average value of waste is estimated at 8.10 USD per ha.

Table 4.10. Average waste of the number of human work hours for samples farms for controlled farms

Efficiency level %	Number of farms	Sample %	Average deficit hr / ha	Average waste USD / ha
100	4	6	0	0
80 – 99	16	22	1.40	2.91
60 – 79	47	64	4.44	9.16
40 – 59	6	8	7.49	15.62
< 39	0	0	0	0
Total	73	100	4	8.10

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

4.3. Results of Measuring Economic Efficiency

The study includes the results of the economic efficiency assessment and the technical and specialized components of the wheat farms that did not control the pest and the farms that control the pest in the research sample for the agricultural season 2017-2018 in the data envelope analysis (DEA) in terms of inputs in light of the amount of resources used in estimating technical efficiency and prices included (prices of purchase of compound fertilizers (dinars), purchase prices of urea fertilizer (USD), wages of machinery work hour (dinars), wages of human work hour (USD). By multiplying the Allocative efficiency (using the statistical program DEA) on technical efficiency VRS,

$$Economic\ Efficiency = Technical\ Efficiency * Allocative\ Efficiency$$

Economic efficiency (EE) ranged between a minimum of 0.85 and a high of 0.955, while the average of technical and allocative efficiency was low 0.260 for the farms that uncontrolled the pest, Suggesting a reduction in farm costs by 0.740 to achieve economic efficiency, ie the farmer can achieve the current amount of production using 0.260 of resources to become economically efficient. Whereas, the farms that included control of the pest ranged between 0.304 and 1, while the average was 0.578, which indicates a reduction in the cost of farms by 0.422 to achieve Economic efficiency, or that the farmer can achieve the current level of production using 0.422 resources to become economically efficient. The farms that were able to achieve the best output with a limited amount of inputs are the same, which achieved both technical efficiency and price efficiency. As they operate within the limits of the equal production curve. So it must continue with the same method of production.

The levels of economic efficiency were low compared to the levels of technical and allocative efficiency of the sample farms themselves, due to the absence of government support and the high costs of agricultural inputs. Especially the high prices of seeds, fertilizers and pesticides, and the nature of the soil and soil texture increases the additional costs of agricultural mechanization of tillage and sowing and crop managements , which increases the number of mechanical working hours, and raises the cost of production, accompanied by the attack sunn pest in the absence of State-controlled management, which causes a decline in productivity, all these factors

combined and others helped to decrease the allocative efficiency and caused the low level of economic efficiency.

Below is a review of economic efficiency and its components, as well as on uncontrolled and controlled farms, for the purpose of clarifying the results. The total economic efficiency and its technical and allocative efficiency were divided into several categories.

4.3.1. Uncontrolled farms

No farm achieved the specialized and economic efficiency of the optimum class 100%, while the number of farms that achieved the allocative efficiency of within the category (80-99%) seven farms accounted for 10% of the number of sample farms, which exceeded the economic efficiency 4 farms, accounted for 7% of the sample farms. In the category 60 - 79%, 10 farms achieved the allocative efficiency accounted for 14% of the number of farms sample and one farm only achieved economic efficiency under this category. Thirty seven 37 farms accounted for 50% of the sample farms achieved technical efficiency limited between 40-59%, while only one farm achieved economic efficiency within this category. It is not surprising to note that 92% of the sample farms achieved economic efficiency under the low category 39% and below which is 67 farm, while 19 farm 26% of the number of sample farms achieved the allocative efficiency, within same category for the reasons mentioned above.

In order to achieve economic efficiency, it is necessary to reduce production costs for the purpose of transferring the line of equal costs in order to be a tangential for the equal output curve. Thus, the farms are technically, allocative and economically efficient. The final result is that the economic efficiency is low compared to the efficiency of its components, but the allocative efficiency was higher than the technical efficiency, where the large cultivated areas have made the allocative efficiency is high.

Note that the level of difict and the level of waste is low in the number of human hours work and the number of mechanical hours work on uncontrolled farms because of the scourge of the sunn pest which destroyed the wheat fields and before maturity and did not farmers harvest their fields.

Table 4.11. The number of uncontrolled farms according to levels of economic efficiency

Efficiency level %	Number of Farms					
	Technical Efficiency	Sample %	Allocative Efficiency	Sample %	Economic Efficiency	Sample %
100	8	11	0	0	0	0
80 – 99	5	7	7	10	4	6
60 – 79	8	11	10	14	1	1
40 – 59	29	39	37	50	1	1
< 39	23	32	19	26	67	92
Total	73	100	73	100	73	100

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

4.3.2. Controlled farms

One farm achieved the optimum allocative and economic efficiency for the optimum category 100%, while the number of farms that achieved allocative efficiency 32 farms accounted for 44% of the number of sample farms within the level 80 - 99%, and did not achieve any farm economic efficiency within this category. The number of farms that achieved the allocative efficiency within the level 60- 79% amounted to 35 farms accounted for 48%, and 32 farms achieved economic efficiency accounted for 44% of the sample farms. Within the category 40 - 59%, 34 farms recorded economic efficiency accounted for 47% of the sample farms, while the number of farms that achieved allocative efficiency were 5 farms accounted for 7%, while 32 farms achieved economic efficiency accounted for 44%. In the last low category, no farm achieved the allocative efficiency, and only 6 farms achieved economic efficiency, constituting 8% of the sample farms.

It should be noted that farms that achieve optimal technical efficiency do not necessarily achieve price efficiency at the optimum level, because of the high costs of the production elements to the extent that lead to the reduction of allocative efficiency at the optimum level, which means that production may be marketed at the point of technical efficiency, But it does not achieve price efficiency. Therefore, the farms will not achieve price and economic efficiency unless the production costs are reduced at the level where the cost line touches the output curve.

Table 4.12. The number of controlled farms according to levels of economic efficiency

Efficiency level %	Number of Farms					
	Technical Efficiency	Sample %	Allocative Efficiency	Sample %	Economic Efficiency	Sample %
100	4	5	1	1	1	1
80 – 99	16	22	32	44	0	0
60 – 79	46	63	35	48	32	44
40 – 59	7	10	5	7	34	47
< 39	0	0	0	0	6	8
Total	73	100	73	100	73	100

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

It is noted that half the number of farms in the controlled farms did not achieve levels of technical efficiency, allocative and economic efficiency within the lower categories of those efficiencies, on the contrary, it is noted that the number of farms that have achieved technical efficiency, economic and allocative has achieved high levels of those efficiencies.

4.4. Estimating the Amount of Resources Achieved for Economic Efficiency

To estimate the size of the resources achieved for the economic efficiency of the sampled farms of the research, that include both uncontrolled and controlled farm from Sunn pest, depending on the use of the method of Data Envelop analysis (DEA) according to the quantity of resources and prices, as the optimal use of economic resources can be calculated by obtaining the minimum amounts of resources achieved for economic efficiency at the lowest average of the total costs at the farm level, which makes it easier to calculate the amount of surplus or deficit compared to the actual resources used, which equals (the amount of resources actually used - the amount of resources achieved for economic efficiency). The results are as follow:

4.4.1. Average quantity of compound fertilizers (DAP)

4.4.1.1. Uncontrolled farms

It is noted that most of the sampled farms achieved low levels of efficiency 39% and below, and included 67 farms representing 92% of the sampled farms with an average

deficit of 109.50 kg / ha, and an average waste of 79.58 USD per ha. While the other six farms were distributed to the rest of the groups Table 4.13. in low rates. While no farm reached the level of full economic efficiency. The average deficit for this resource was 102.019 kg / ha and the estimated waste value was 74.07 USD per ha. This deterioration of low rates of efficiency is due to the infection of the crop with sunn pest and the lack of coverage to control these farms, either due to poor management efficiency in terms of pesticide use or inaccuracy in the timing of control. These results indicate that the same production can be achieved in quantity of compound fertilizers less than the actual quantity used.

Table 4.13. Average waste of compound fertilizers for samples farms for uncontrolled farms

Efficiency level %	Number of farms	Sample %	Average deficit Kg/ha	Average waste USD /ha
100	**0**	**0**	**0**	**0**
80 – 99	**4**	**6**	**16.53**	**12.08**
60 – 79	**1**	**1**	**4.42**	**3.16**
40 – 59	**1**	**1**	**70.92**	**51.66**
< 39	**67**	**92**	**109.050**	**79.58**
Total	**73**	**100**	**102.019**	**74.07**

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

4.4.1.2. Controlled farms

Most of the 66 farms of the sampled farms were distributed in the middle categories Table 4.14. of the levels of efficiency ranged between the category 60-79%, these included 32 farms accounted for 44% of the sampled farms, with average deficit of (56.318) kg/ha, and average waste of 41.14 USD per ha. Beside, 34 farms achieved levels of efficiency ranged between 40 - 59% accounted for 47% of the number of sampled farms, with average deficit 71.122 kg/ha, and average waste of 51.85 USD / ha. While low rates were achieved in 6 farms accounted for 8% of the sampled farms, the average deficit was 108.500 kg / ha, and average waste of 79.16 USD / ha. While the full economic efficiency had only one farm. Indicating that although these farms included the control of the pest of the sunn or other insects, they are subject to factors

negatively affected the average efficiency, with an average deficit 74.323 and an average waste 50.27 USD per ha.

It should be noted that the control will reduce the amount of compound fertilizers achieved for economic efficiency in the sense that indicate the efficiency of resource utilization, and can achieve the same level of production in the amount of compound fertilizers achieved efficiency is much less than the amount of actual seeds used.

Table 4.14. Average waste of compound fertilizers for samples farms for controlled farms

Efficiency level %	Number of farms	Sample %	Average deficit Kg/ha	Average waste USD /ha
100	1	1	0	0
80 – 99	0	0	0	0
60 – 79	32	44	56.318	41.06
40 – 59	34	47	71.122	38.89
< 39	6	8	108.5	79.16
Total	73	100	74.323	50.27

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

4.4.2. The average amount of nitrogen fertilizers (Urea)

4.4.2.1. Uncontrolled farms

It is noted that most of the sample farms achieved low levels of efficiency 39% and below, including 67 farms representing 92% of the sampled farms. The average deficit was 110.382 kg / ha, and an average waste of 76.66 USD / ha, while the six farms left were distributed to the rest of the groups Table 4.15. in low rates. While no farm reached the level of full economic efficiency, and the average deficit of this resource in general 101.311, and average waste of 71.90 USD per ha. This deterioration of the efficiency is due to the infection of the crop with sunn pest and the lack of coverage of these farms to pest control, and due to the poor management efficiency of the pesticide used or the inaccuracy in the timing of the control. These results indicate that the same production can be achieved with less compound fertilizer than the actual quantity used.

Table 4.15. Average waste of nitrogen fertilizers for samples farms for uncontrolled farms

Efficiency level %	Number of farms	Sample %	Average deficit Kg/ha	Average waste USD /ha
100	**0**	**0**	**0**	**0**
80 – 99	**4**	**6**	**15.556**	**10.70**
60 – 79	**1**	**1**	**94.56**	**65**
40 – 59	**1**	**1**	**7.072**	**4.861**
< 39	**67**	**92**	**110.382**	**76.66**
Total	**73**	**100**	**101.311**	**71.90**

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

4.4.2.2. Controlled farms

Most of the 66 farms of the sampled farms were divided into the middle categories Table 4.16. of the levels of efficiency ranged between the category 60-79%, which included 32 farms constituting 44% of the sampled farms, the average deficit was 66.523 kg / ha and the average waste of 45.83 USD per ha. Also, 34 farms achieved levels of efficiency ranged between 40-59% accounted for 47% of the sampled farms with average deficit of 88.252 kg / ha and average waste of 60.72 USD per ha. While the lowest efficiency were recorded by 6 farms representing 8% of the sampled farms with an average deficit of 119,023 kg / ha and an average waste of 81.66 USD per ha, while only one farm was fully economically efficient. Indicating that although these farms included the control of the pest of the sunn or other insects, they are subject to factors negatively affected the average efficiency, with an average deficit 81.158 and the average waste 55.84 USD per ha. It should be noted that the control will reduce the amount of nitrogenous fertilizer (urea) achieved for economic efficiency in the sense that indicates the efficiency of exploitation of resources, and can achieve the same level of production with less than the amount of nitrogen fertilizer (Urea) actually used.

Table 4.16. Average waste of nitrogen fertilizers for samples farms for controlled farms

Efficiency level %	Number of farms	Sample %	Average deficit Kg/ha	Average waste USD /ha
100	1	1	0	0
80 – 99	0	0	0	0
60 – 79	32	44	66.523	45.83
40 – 59	34	47	88.252	60.72
< 39	6	8	119.023	81.66
Total	73	100	81.158	55.84

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

4.4.3. Average number of machinery work hours

4.4.3.1. Uncontrolled farms

It is noted that most of the sample farms achieved low levels of efficiency 39% and below, including 67 farms representing 92% of the sampled farms. The average deficit was 16.85 hour / ha, and an average waste of 70 USD / ha, while the six farms left were distributed to the rest of the groups Table 4.17. in low rates. While no farm reached the level of full economic efficiency, and the average deficit of this resource in general 15.46 Kg, and average waste of 66.78 USD per ha. This deterioration of the efficiency is due to the infection of the crop with sunn pest and the lack of coverage of these farms to pest control, and due to the poor management efficiency of the pesticide used or the inaccuracy in the timing of the control. These results indicate that the same production can be achieved with fewer worked hours than the actual hours used.

Table 4.17. Average waste of number of machinery work hours for samples farms for uncontrolled farms

Efficiency level %	Number of farms	Sample %	Average deficit hour/ha	Average waste USD /ha
100	0	0	0	0
80 – 99	4	6	1.73	7.08
60 – 79	1	1	15.36	64
40 – 59	1	1	6.36	25.83
< 39	67	92	16.85	70
Total	73	100	15.46	66.78

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

4.4.3.2. Controlled farms

Most of the 66 farms of the sampled farms were distributed in the middle categories Table 4.18. of the levels of efficiency ranged between the category 60-79%, these included 32 farms accounted for 44% of the sampled farms, with average deficit of 4.51 hour/ha, and average waste of 18.33 USD per ha. Beside, 34 farms achieved levels of efficiency ranged between 40 - 59% accounted for 47% of the number of sampled farms, with average deficit 12.91 hour/ha , and average waste of 32.08 USD / ha. While low rates were achieved in 6 farms accounted for (8%) of the sampled farms, the average deficit was 12.91 hour / ha, and average waste of 53.75 USD / ha. While the full economic efficiency had only one farm. Indicating that although these farms included the control of the pest of the sunn or other insects, they are subject to factors negatively affected the average efficiency, with an average deficit 6.71 and an average waste 27.77 USD per ha.

It should be noted that the worked machinery hours achieved for economic efficiency in the sense that indicate the increase the efficiency of resource utilization, and can achieve the same level of production in the amount of worked machinery hours achieved efficiency is much less than the actual worked machinery hours.

Table 4.18. Average waste of number of machinery work hours for samples farms for controlled farms

Efficiency level %	Number of farms	Sample %	Average deficit hour/ha	Average waste USD /ha
100	**1**	**1**	**0**	**0**
80 – 99	**0**	**0**	**0**	**0**
60 – 79	**32**	**44**	**4.51**	**18.33**
40 – 59	**34**	**47**	**7.70**	**32.08**
< 39	**6**	**8**	**12.91**	**53.75**
Total	**73**	**100**	**6.71**	**27.77**

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

4.4.4. Average number of human work hours

4.4.4.1. Uncontrolled farm

It is noted that most of the sample farms achieved low levels of efficiency 39% and below, including 67 farms representing 92% of the sampled farms. The average deficit was 24.53 hour / ha, and an average waste of 50.83 USD / ha, while the six farms left were distributed to the rest of the groups Table 4.19. in low rates. While no farm reached the level of full economic efficiency, and the average deficit of this resource in general 23.024, and average waste of 47.71 USD per ha. This deterioration of the efficiency is due to the infection of the crop with sunn pest and the lack of coverage of these farms to pest control, and due to the poor management efficiency of the pesticide used or the inaccuracy in the timing of the control. These results indicate that the same production can be achieved with fewer human worked hours than the actual hours used.

Table 4.19. Average waste of number of human work hours for samples farms for uncontrolled farms

Efficiency level %	Number of farms	Sample %	Average deficit hour/ha	Average waste USD /ha
100	**0**	**0**	**0**	**0**
80 – 99	**4**	**6**	**4**	**6.50**
60 – 79	**1**	**1**	**1**	**9.31**
40 – 59	**1**	**1**	**1**	**42.29**
< 39	**67**	**92**	**67**	**50.83**

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

4.4.4.2. Controlled farms

Most of the 66 farms of the sampled farms were distributed in the middle categories Table 4.20. of the levels of efficiency ranged between the category 60-79%, these included 32 farms accounted for 44% of the sampled farms, with average deficit of 4.68 hour / ha, and average waste of 10 USD per ha. Beside, 34 farms achieved levels of efficiency ranged between 40 - 59% accounted for 47% of the number of sampled farms, with average deficit 6.95 hour/ha, and average waste of 14.16 USD / ha. While low rates were achieved in 6 farms accounted for 8% of the sampled farms, the average

deficit was 10.23 hour / ha, and average waste of 20.83 USD / ha. While the full economic efficiency had only one farm. Indicating that although these farms included the control of the pest of the sunn or other insects, they are subject to factors negatively affected the average efficiency, with an average deficit 6.21 and an average waste 12.91 USD per ha.

It should be noted that the control of the pest will reduce human worked hours achieved for economic efficiency in the sense that indicate the increase the efficiency of resource utilization, and can achieve the same level of production in the amount of worked machinery hours achieved efficiency is much less than the actual human worked hours.

Table 4.20. Average waste of number of human work hours for samples farms for controlled farms

Efficiency level %	Number of farms	Sample %	Average deficit hour/ha	Average waste USD /ha
100	**1**	**1**	**0**	**0**
80 – 99	**0**	**0**	**0**	**0**
60 – 79	**32**	**44**	**4.68**	**10**
40 – 59	**34**	**47**	**6.95**	**14.16**
< 39	**6**	**8**	**10.23**	**20.83**
Total	**73**	**100**	**6.21**	**12.91**

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

4.5. Results of Farmers' Survey on Sunn Pest Management

Table 4.21 revealed that 42% of the farmers observed disease or arthropod pest in their field; 74.7% of farmers think all the insects in their field are harmful. Only 33.6% can recognize the sunn pest in their field. Farmers expressed that they have had sunn pest problems for an average of 2 years. Farmers see the sunn pest in the field for the first time in mid-April and 71.2% think that pesticides should be immediately sprayed once the sunn pest is first seen in the field. Despite 89.7% of farmers did not think of any other solution for the sunn pest problem apart from chemical pesticides, only 32.9% know how to decide to spray chemicals against the sunn pest. Only 13% of the farmers know how to measure the success of the chemical insecticides used against the sunn pest, and only 14.4% of them would like to get educated about the sunn pest. The

responded of the knowledge about the side effects of chemical pesticides was 15.8%. Only 25.3% of the farmers go to their field to check during the sunn pest management.

Table 4.21. Farmers' evaluation on sunn pest and its control

Evaluation	Frequency	Yes	No	Mean
Is there any disease or arthropod pest in your field or in your garden?	N	61	85	0.42
	%	41.8	58.2	
Do you think all the insects you see in your field are harmful?	N	109	37	0.25
	%	74.7	25.3	
Can you recognize the sunn pest *(Eurygaster integriceps*)?	N	49	97	0.34
	%	33.6	66.4	
Do you think pesticides should be immediately sprayed once the sunn pest is first seen in the field?	N	104	42	0.71
	%	71.2	28.8	
Have you thought of any other solution for the sunn pest problem apart from chemical pesticides?	N	15	131	0.10
	%	10.3	89.7	
Do you know how to decide to spray chemicals against the sunn pest?	N	48	98	0.67
	%	32.9	67.1	
Do you know how to measure the success of the chemical insecticides used against the sunn pest?	N	19	127	0.13
	%	13.0	87.0	
Would you like to get educated about the sunn pest?	N	21	125	0.14
	%	14.4	85.6	
Do you know about the side effects of chemical pesticides	N	23	123	0.16
	%	15.8	84.2	
Do you go to your field to check during the sunn pest management?	N	37	109	0.25
	%	25.3	74.4	

In Table 4.22, data related to farmers' evaluation of sunn pest are given. Farmers responded to the question about kind of pest and diseases in their fields; 59.6% were pest and diseases, 4.1% bugs and worms, 19.9 % weeds, 19.9% fungi, and 4.1% field mouse.

The recognition of adult sunn pest by farmers was 28.1% while 12.3% could identify sunn pest eggs, and 25.3% could identify larva stage of sunn pest.

Table 4.22. Farmers' evaluation on sunn pest and its control (Continued)

What kind of pest and diseases do you have in your wheat?						
Evaluation	Frequency	Yes	No	I don't know	Mean Likert Scale	
Pest and diseases	N	87	36	23	0.91	Yes
	%	59.6	24.7	15.8		
Worm and Bug	N	6	119	21	0.33	No
	%	4.1	81.5	14.4		
Weed	N	29	107	10	0.34	No
	%	19.9	73.3	6.8		
Fungi	N	29	102	15	0.40	No
	%	19.9	69.9	10.2		
Field mouse	N	6	132	8	0.15	No
	%	4.1	90.4	5.5		
What kind of pest and diseases do you have in your wheat?						
Evaluation	Frequency	Yes	No	I don't know	Mean likert scale	
Adult	N	41	92	13	0.46	No
	%	28.1	63.0	8.9		
Egg	N	18	117	11	0.27	No
	%	12.3	80.1	7.5		
Larva	N	37	97	12	0.42	No
	%	25.3	66.4	8.2		

Questions were asked to indicate Yes , No, or I don't know. Where 0= No 1=yes 2=I don't know

In Table 4.23 data related to farmers' knowledge evaluation of sunn pest are given. Farmers have middle knowledge about sunn pest damage 52.7%. Farmers have fairly high knowledge about beneficial insects 70.5%. Farmers do not feel they have enough information about sunn pest 61.6% and 71.2% of the responded farmers do not have enough knowledge about the side effects of chemical pesticides. In addition, 56.2 of the responded farmers don't know about the effects of chemical pesticides applied with airplane on the environment and human health.

Table 4.23. Farmers' evaluation knowledge on sunn pest and its control

Evaluation	Scale	I don't know	I know little	I know	I know well	I know very well	Mean Likert Scale	Likert Result
Do you know what kind of damage the sunn pest	Freq.	77	23	24	12	10	1.01	I know little
	%	52.7	15.8	16.4	8.2	6.8		
Do you have any information about beneficial	Freq.	103	14	13	10	6	0.64	I don't know
	%	70.5	9.6	8.9	6.8	4.1		
Do you think your knowledge about the sunn	Freq.	90	20	17	12	7	0.81	I know little
	%	61.6	13.7	11.6	8.2	4.8		
Do you know about the side effects of chemical pesticide	Freq.	104	20	9	7	6	0.65	I don't know
	%	71.2	13.7	6.2	4.8	4.1		
Do you know about the effects of chemical pesticides applied with airplane on the environment and human health?	Freq.	82	62	2	0	0	0.45	I don't know
	%	56.2	42.5	1.4	0	0		

When the farmers were asked about where they get information about the sunn pest, 67.1% said from Provincial Directorate of Agriculture, 24.7% responded from chamber of agriculture, while only 8.2% said from family Table 4.24.

Table 4.24. Farmers' evaluation getting information about the sunn pest

Where do you get information about the Sunn pest?		
	Frequency	Percent
Provincial Directorate of Agriculture	98	67.1
Chamber of Agriculture	36	24.7
Family	12	8.2
Total	146	100.0

Farmers' evaluation about the their opinion on which management system they do think is more successful conducted in the previous years, only 85.6% responded that airplane application is more efficient, while 6.2% of farmers responded that application with ground equipment is more successful Table 4.25.

Table 4.25. Farmers evaluation of the successful application of the sunn pest control

Which management system do you think is more successful conducted in the previous years?		
	Frequency	Percent
Airplane application	125	85.6
Application with ground equipment	9	6.2
Other	12	8.2
Total	146	100.0

The farmers responses about what they do when they see the sunn pest on their field, 64.4% said they do nothing while 28.8% said they notify relevant authorities, of which 83% of them notify Directorate of Agriculture, and 16.7% notify President of the Local Council Table 4.26 and 4.27.

Table 4.26. Farmers evaluation of notification of sunn pest

What do you do when you see the sunn pest on your field?		
	Frequency	Percent
Nothing	94	64.4
I notify relevant authorities	42	28.8
Others	10	6.8
Total	146	100.0

Table 4.27. Farmers notification of sunn pest to the authorities

who do you notify the situation?		
	Frequency	Percent
Directorate of Agriculture	35	83.3
President of the Local Council	7	16.7
Total	42	100.0

4.6. Results of university staffs' survey on sunn pest management

A total of 6 members of university staffs were surveyed. The responded answers to questions concerned about sunn pest management were presented in Table 4.28. Total of 66.7% of the university staffs believe that the economic threshold for the sunn pest works. But, all the staff who filled out the questionnaire don't believe to continue the management of sunn pest in this situation, because of the lack of the economic thresholds in Iraq for all insects, including the sunn pest and because it causes economic loss in pesticides and control effort. All university staff believe that a managfement system of sunn pest in the frame work of Integrated Pest Management (IPM) is the alternative one to the only chemical control. Also, 33.3% from the university staffs believed that the management of sunn pest is carried out in the place and time where the administration is needed. One third of the responders believes that there are reasons other than technical reasons for decision taking against the sunn pest, including the security declaration of control. "The management of the government of the sunn pest control is believed to be insufficient", said 100% of the responders because of:

1. Insufficient staff
2. Insufficient insecticide
3. Producer indifference
4. Delays in the application of control measures (insecticides)
5. Lack of biological control applications and centers in Iraq

The dialogue between technical staff and farmers is good by 33.3 % and normal by 66.7%. This dialogue affects the success of the management of the sunn pest by 100%. In addition, "The number of employees working in the management of the pest is insufficient" said 100% of the responders. Besides, staff education is inadequate and they need training courses.

The most important problems in the management of the sunn pest in Iraq are the lack of field staffs and lack of activity of the extensionists as well as the lack of centers of biological control in Iraq, and that legislative measures do not exist such as quarantine. The staff working in the management of the sunn pest were not changed frequently.

With the answer to the question " Do you think that the technical and administrative system in the management of the sunn pest work well?", fifty percent think that it does not work as a real reality in all the provinces of Iraq. It may work in Baghdad with simple applications. The reason for that pesticides are not applied in a timely manner to control the sunn pest and there are no Integrated Pest Management (IPM) centers and Biological Control Centers in Iraq.

All the university staffs said that the Government does not appoint a regional coordinator, but they suggest that a regional coordinator should be appointed. All the responders believed that when the management instructions of the sunn pest are applied, the control measures give good results. Also, all university staffs believe that chemical insecticides are not available when farmers need them because the management of the sunn pest is done by the government. The university staffs' opinion about "suitable type of insecticide application" (ultra-low volume (ULV) or conventional), was "ULV application with the aircraft to secure control speed for large areas of wheat fields. Therefore two third 66.7% of responders prefer applying pesticides with airplane rather than ground spraying Besides, 33.3% of them get satisfied with the aereal application of insecticides because it is done according to the appropirate technical instructions and the pilots' experience is sufficient. Two third 66.7% believes that the pilots don't pay enough attention to the application of insecticides to be done correctly, in addition, they believes that airfields were not prepared well for suitable flight conditions.

All the university staffs check the wheat grain damage to measure the success of the control at the end of the sunn pest management. One third 33.3% of the responders have research done on the sunn pest. All the responders think that researches done in their institution on sunn pest is insufficient, and suggest conduct more studies at the level of each governorate of Iraq. Biological, environmental and seasonal studies should be conducted so that they can conduct an Integrated Pest Management.

Table 4.28. University staff evaluation on sunn pest and its control

Evaluation	Frequency	Yes	No
Do you think that the economic threshold used for the sunn pest works?	N	4	2
	%	66.7	33.3
Is it appropriate to continue the management of sunn pest in this situation?	N	0	6
	%	0	100
Do you think that the control of sunn pests is being done in the place where the management is needed?	N	2	4
	%	33.3	66.7
Do you think that the control of sunn pests is being done in the time where the management is needed?	N	6	0
	%	100	0
Is there any other reason other than technical reasons to take the decisions of the control in the management of	N	2	4
	%	33.3	66.7
Do you think the management of sunn pest conducted by the government is well enough?	N	0	6
	%	0	100
Do these dialogues affect the success of the management?	N	6	3
	%	66.7	33.3
Do you think that the number of staff who are in charge of sunn pest management is sufficient?	N	0	6
	%	0	100
Do you think that the education of staff who are in charge of the management is sufficient?	N	0	6
	%	0	100
Is the staff in the management of sunn pest changed frequently?	N	0	6
	%	0	100
Does Government appoint any regional coordinator for the sunn pest management?	N	0	6
	%	0	100
Do the insecticides used in the management of the sunn pest give good results when the technical instructions are fulfilled?	N	6	0
	%	100	0
Are the insecticides available when you need them?	N	0	6
	%	0	100
Is the application of insecticides with airplane done according to the technique satisfactorily?	N	2	4
	%	33.3	66.7
Is the pilot's experience sufficient?	N	2	4
	%	33.3	66.7
Do the pilots pay enough attention to the application of insecticides to be done correctly?	N	2	4
	%	33.3	66.7
Are airfields prepared suitable for flight conditions?	N	2	4
	%	33.3	66.7
Do you check the wheat grain damage to measure the success of the control at the end of the sunn pest management?	N	6	0
	%	100	0
Do you have any research that you have done on the sunn pest?	N	2	4
	%	33.3	66.7
Do you think that researches done in your institution on sunn pest is sufficient?	N	0	6
	%	0	100

4.7. Results of the Farmers' Union Survey on Sunn Pest Management

The respond to the question asked to the farmers' union " How do you distinguish the harm that sunn pest make on wheat from the harm caused by the other organisms?" was that the damage caused by the sunn pest can be identified by increasing the number of white spike, at a time when the other ears are green and not full. Whereas, after harvest, the infection can be distinguished by examining the seeds, which are black scar, surrounded by a white halo.

The answer to the question "How does the sunn pest affect the price of the wheat you buy and how do you arrange pricing", was that the infected wheat can be distinguished by its rate according to the rate of kernel damage. The first degree, for which the price is 480 USD per tonne, is the kernel damage of 2%, and if the kernel damage is 4-6%, the price is 400 USD per tonne. In the third degree, which kernel damage should not be more than 10%, the price is 280 USD per tonne. When kernel damage rate exceed 10%, the crop is rejected and marketed to local markets and the price is 200 USD per tonne. In addition, They also said that the experience of their experts in charge of wheat buying is not enough in distinguishing the damage of sunn pest. So, most of the people in charge need training in how to distinguish the infected grain from sunn pest from uninfected seeds.

4.8. Results of Chambers of Trade Survey

Responding to questions for chambers shows the following;

They know the organization (working system) in the management of sunn pest.

They receive complaints from the farmers about sunn pest.

They communicate with Reeve when they receive complaints.

They partially satisfied with the management of sunn pest.

They would like to take part in the management of sunn pest as an organization of farmers.

They contribute to take a part in the management of sunn pest as an organization of farmers through early detection of the infection.

CHAPTER 5

CONCLUSION

The uncontrolled farms were at low levels of return capacity 39% or less. They represent 88% of the sample farmers operating under constant return to scale (CRS). The efficiency in variable return of scale was 71% of the number of sample farms distributed over the last two categories 59-40% and 39% and below. While the opposite is observed in the controlled farms, the numbers were concentrated in the return of scale over the last two categories first and second (80-99%) and 100%. As the number of farms according to the return of capacity 82% of the number of farms of this sample which indicates that the lack of coverage of these farms to the pest control will be further deterioration of technical efficiency, that the inclusion of farms in the control management program will lead to raising the levels of 88% of farms that are not covered by control from low levels of 39% or below to 99%, This means exploitation of more than 50% of the productivity of resources is used to serve the crop. It is therefore possible to recommend the inclusion of the largest number of farms in the control management program to raise the level of technical efficiency and benefit from the resources that were wasted as a result of non-control.

The declining of technical efficiency of the uncontrolled farms was reflected in their allocative and economic efficiency, The percentage of farms with less than 39% of economic efficiency to 92% of the sampled farms, this can be used to infer the economic inefficiency of crop cultivation in the absence of a program to manage the sunn pest, the costs cannot be reduced to what they are, this confirms the high levels of economic efficiency on the controlled farms, the allocative efficiency reached 92% of the sampled farms were limited to 60% of the allocative efficiency and higher. We conclude from this that there is an economic waste that can be avoided by concentrating and controlling the management program against the sunn pest.

Resources achieved for technical efficiency

The average deficit of the compound fertilizer was 87 and 42.161 kg / ha for uncontrolled and controlled farms, respectively, where the average waste was 63.36 and 30.77 USD / ha respectively .The average deficit for urea fertilizer was 86.507, 49.057 kg / ha for uncontrolled and controlled farms respectively, where the average waste was 59.54, 33.44 USD / ha respectively. The average deficit for machinery work hours was 10.40 and 15.27 hr / ha for uncontrolled and controlled farms respectively, where the average waste was 43.33 and 33.44 USD / ha respectively. The average deficit for human work hours was 19.085 and 4.00 hr / ha for uncontrolled and controlled farms respectively, where the average waste was 39.67and 8.105 USD / ha respectively. We conclude from this that the control management factor is the main indicator of the low resources achieved for the technical efficiency of these farms. While in the controlled farms we note a decrease in the average deficit in the economically degraded groups as well as a decline in the number of farms in those categories.

Resources achieved for economic efficiency

The average deficit of the compound fertilizer was 102.019 and 74.323 kg / ha for uncontrolled and controlled farms, respectively, where the average waste was 74.07 and 50.27 USD / ha respectively. The average deficit for urea fertilizer was 101.311, 81.158 kg / ha for uncontrolled and controlled farms respectively, where the average waste was 71.90, 55.84 USD / ha respectively. The average deficit for machinery work hours was 15.46 and 6.71 hr / ha for uncontrolled and controlled farms respectively, where the average waste was 66.78 and 27.77 USD / ha respectively. The average deficit for human work hours was 23 and 6.21 hr / ha for uncontrolled and controlled farms respectively, where the average waste was 47.91 and 12.91 USD / ha respectively.

To preserve these economic resources from waste and loss, creating an integrated program linking the agricultural work structure in conjunction with the sunn pest management program is very important. We conclude from an increase in the average deficit and economic loss for the uncontrolled farms that the control management factor is the main indicator of the low resources achieved for the technical and economic efficiency of these farms. While in the controlled farms we note a decrease in the

average deficit in the economically degraded groups as well as a decline in the number of farms in those categories.

Sunn pest has been a major insect pest of cereals for hundreds of years. Research has focused on management techniques to keep the pest population under the economic threshold level. However, increasing demand for cereal-based foods especially in developing countries carries concerns about the future of food security in sunn pest-prone regions. The results concluded from questionnaire revealed that the knowledge level of farmers is weak because the scourge of sunn pest is new in the central region due to the availability of overwintering sites (hibernation). What is required at this stage is to focus on educating farmers by introducing them in induction training courses on the recognition of the growth stages of the pest and prevention and control methods. As well as education of farmers, the cooperation of state institutions through the provision of appropriate pesticides, spray aircraft and professional pilots for large areas, and through the provision and education on the types of equipment used to control is very important to manage the sunn pest. In addition, appropriate timing of control, and the optimum use of chemical pesticides will reduce environmental pollution.

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APPENDIXS

Appendix A. Technincal Efficiency Analysis

Table 1. Results of the estimation of technical efficiency of wheat cultivation research sample for the 2017-2018 growing season according to the Envelope Data Method (EDA) analysis.

Uncontrolled farms					Controlled farms				
N	Efficiency according to constant return to the scale	Efficiency according to variable return to the scale	Efficiency of the scale	Return of the scale	N	Efficiency according to constant return to the scale	Efficiency according to variable return to the scale	Efficiency of the scale	Return of the scale
1	0.225	0.33	0.681	Irs	1	0.585	0.653	0.897	Irs
2	0.139	1	0.139	Irs	2	0.633	0.651	0.973	Irs
3	0.34	0.455	0.748	Irs	3	0.376	0.563	0.668	Irs
4	0.052	0.212	0.247	Irs	4	0.849	0.889	0.954	Irs
5	0.372	0.518	0.717	Irs	5	0.89	0.936	0.951	Irs
6	0.28	0.405	0.692	Irs	6	0.683	0.775	0.906	Irs
7	0.577	0.726	0.795	Irs	7	0.789	0.814	0.969	Irs
8	0.572	1	0.572	Irs	8	0.736	0.776	0.949	Irs
9	0.374	0.774	0.483	Irs	9	0.876	0.983	0.89	Irs
10	0.337	0.779	0.433	Irs	10	0.644	0.908	0.709	Irs
11	0.027	0.251	0.108	Irs	11	0.584	0.675	0.865	Irs
12	0.031	0.251	0.121	Irs	12	0.803	0.804	0.999	Irs
13	0.155	0.295	0.524	Irs	13	0.658	0.979	0.672	Irs
14	0.296	0.404	0.733	Irs	14	0.73	0.7764	0.956	Irs
15	0.023	0.189	0.123	Irs	15	0.458	0.59	0.776	Irs
16	0.141	1	0.141	Irs	16	0.69	0.725	0.953	Irs
17	0.02	0.224	0.088	Irs	17	0.672	0.712	0.945	Irs
18	0.212	0.357	0.596	Irs	18	0.673	0.748	0.899	Irs
19	0.501	0.926	0.541	Irs	19	0.671	0.725	0.926	Irs
20	0.34	0.466	0.728	Irs	20	0.836	0.953	0.877	Irs
21	0.099	0.261	0.38	Irs	21	1	1	1	-
22	0.02	0.224	0.088	Irs	22	0.693	0.803	0.862	Irs
23	0.085	0.207	0.411	Irs	23	0.587	0.641	0.915	Irs
24	0.149	0.33	0.45	Irs	24	0.752	0.782	0.961	Irs
25	0.18	0.303	0.596	Irs	25	0.558	0.678	0.823	Irs
26	0.233	0.547	0.426	Irs	26	0.619	0.687	0.901	Irs
27	0.516	0.778	0.664	Irs	27	0.608	0.957	0.635	Irs
28	0.094	0.238	0.394	Irs	28	0.492	0.585	0.84	Irs
29	0.386	0.658	0.587	Irs	29	0.56	0.694	0.806	Irs
30	0.259	0.408	0.635	Irs	30	0.73	0.744	0.981	Irs
31	0.26	0.416	0.624	Irs	31	0.453	0.575	0.787	Irs
32	0.679	0.834	0.815	Irs	32	0.589	0.687	0.857	Irs
33	0.076	0.306	0.247	Irs	33	0.438	0.626	0.699	Irs
34	0.574	0.786	0.731	Irs	34	0.525	0.689	0.762	Irs
35	0.144	0.337	0.427	Irs	35	0.664	0.728	0.912	Irs
36	0.216	0.393	0.55	Irs	36	0.67	0.72	0.93	Irs
37	0.262	1	0.262	Irs	37	0.768	0.794	0.968	Irs
38	0.256	0.405	0.632	Irs	38	0.718	0.781	0.919	Irs
39	0.152	0.309	0.49	Irs	39	0.734	0.795	0.922	Irs
40	0.135	0.419	0.321	Irs	40	0.867	1	0.867	Irs
41	0.11	0.357	0.31	Irs	41	0.73	0.96	0.76	Irs
42	0.094	0.309	0.305	Irs	42	0.609	0.698	0.872	Irs
43	0.112	0.337	0.332	Irs	43	0.573	0.641	0.895	Irs
44	0.295	1	0.295	Irs	44	0.573	0.783	0.731	Irs
45	0.128	0.847	0.151	Irs	45	0.723	0.794	0.911	Irs
46	0.24	0.42	0.572	Irs	46	0.813	0.844	0.963	Irs
47	0.119	0.273	0.434	Irs	47	0.478	0.566	0.845	Irs

48	0.45	1	0.45	Irs	48	0.452	0.58	0.779	Irs
49	0.252	0.437	0.578	Irs	49	0.688	0.753	0.914	Irs
50	0.25	0.425	0.587	Irs	50	0.701	0.714	0.981	Irs
51	0.195	0.459	0.425	Irs	51	0.576	0.617	0.934	Irs
52	0.4	0.587	0.682	Irs	52	0.754	0.761	0.99	Irs
53	0.126	0.511	0.246	Irs	53	0.684	0.723	0.946	Irs
54	0.358	0.559	0.641	Irs	54	0.625	0.737	0.848	Irs
55	0.29	0.453	0.64	Irs	55	0.702	0.726	0.968	Irs
56	0.322	0.517	0.623	Irs	56	0.714	0.802	0.891	Irs
57	0.28	0.445	0.63	Irs	57	0.691	0.721	0.958	Irs
58	0.026	0.43	0.061	Irs	58	0.549	0.743	0.739	Irs
59	0.567	1	0.567	Irs	59	0.658	0.735	0.895	Irs
60	0.189	0.587	0.321	Irs	60	0.772	1	0.772	Irs
61	0.202	0.52	0.389	Irs	61	0.752	0.765	0.983	Irs
62	0.163	0.539	0.301	Irs	62	0.55	0.667	0.825	Irs
63	0.042	0.625	0.065	Irs	63	0.571	0.644	0.888	Irs
64	0.027	0.433	0.063	Irs	64	0.7	0.766	0.913	Irs
65	0.166	0.436	0.38	Irs	65	0.623	0.651	0.927	Irs
66	0.194	0.508	0.382	Irs	66	0.65	0.702	0.926	Irs
67	0.338	0.591	0.572	Irs	67	0.81	0.848	0.955	Irs
68	0.229	0.667	0.343	Irs	68	0.682	0.717	0.951	Irs
69	0.253	0.574	0.441	Irs	69	0.751	0.889	0.845	Irs
70	0.279	1	0.279	Irs	70	0.765	0.846	0.904	Irs
71	0.026	0.1	0.259	Irs	71	1	1	1	-
72	0.098	0.824	0.119	Irs	72	0.673	0.71	0.948	Irs
73	0.164	0.801	0.205	Irs	73	0.666	0.69	0.966	Irs
Mean	0.229	0.524	0.432		Mean	0.672	0.758	0.886	

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

Appendix B. Estimating the amount of resources achieved for technical efficiency

Table 1. The average amount of compound fertilizer obtained for the technical efficiency of wheat farming, for uncontrolled farms for growing season 2017-2018

N	actual use of Compound fertilizer (kg/ha)	compound fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)	N	actual use of Compound fertilizer (kg/ha)	compound fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)
1	160	52.8	107.2	38	160	64.8	95.2
2	160	160	0	39	160	49.44	110.56
3	120	54.6	65.4	40	200	83.8	116.2
4	160	33.92	126.08	41	160	57.12	102.88
5	160	82.88	77.12	42	160	49.44	110.56
6	160	64.8	95.2	43	200	67.4	132.6
7	36	26.136	9.864	44	16	16	0
8	20	20	0	45	36	30.492	5.508
9	32	24.768	7.232	46	120	50.4	69.6
10	28	21.812	6.188	47	160	43.68	116.32
11	120	30.12	89.88	48	28	28	0
12	200	50.2	149.8	49	160	69.92	90.08
13	160	47.2	112.8	50	160	68	92
14	160	64.64	95.36	51	200	91.8	108.2
15	200	37.8	162.2	52	160	93.92	66.08
16	20	20	0	53	160	81.76	78.24
17	200	44.8	155.2	54	200	111.8	88.2
18	200	71.4	128.6	55	160	72.48	87.52
19	28	25.928	2.072	56	200	103.4	96.6
20	120	55.92	64.08	57	160	71.2	88.8
21	160	41.76	118.24	58	160	68.8	91.2
22	200	44.8	155.2	59	32	32	0
23	200	41.4	158.6	60	200	117.4	82.6
24	120	39.6	80.4	61	160	83.2	76.8
25	160	48.48	111.52	62	120	64.68	55.32
26	80	43.76	36.24	63	160	100	60
27	160	124.48	35.52	64	160	69.28	90.72
28	160	38.08	121.92	65	160	69.76	90.24
29	120	78.96	41.04	66	120	60.96	59.04
30	200	81.6	118.4	67	120	70.92	49.08
31	200	83.2	116.8	68	200	133.4	66.6
32	24	20.016	3.984	69	160	91.84	68.16
33	200	61.2	138.8	70	36	36	0
34	180	141.48	38.52	71	240	24	216
35	200	67.4	132.6	72	28	23.072	4.928
36	120	47.16	72.84	73	200	160.2	39.8
37	32	32	0	Mean	139.397	62.129	77.267

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

Table 2. The average amount of compound fertilizer obtained for the technical efficiency of wheat farming, for controlled farms for growing season 2017-2018

N	actual use of Compound fertilizer (kg/ha)	Compound fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)	N	actual use of Compound fertilizer (kg/ha)	Compound fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)
1	160	104.48	55.52	38	200	156.2	43.8
2	200	130.2	69.8	39	160	127.2	32.8
3	160	90.08	69.92	40	160	160	0
4	160	142.24	17.76	41	200	192	8
5	160	149.76	10.24	42	160	111.68	48.32
6	140	108.5	31.5	43	160	102.56	57.44
7	160	130.24	29.76	44	140	109.62	30.38
8	160	124.16	35.84	45	160	127.04	32.96
9	120	117.96	2.04	46	160	135.04	24.96
10	160	145.28	14.72	47	160	90.56	69.44
11	160	108	52	48	140	81.2	58.8
12	200	160.8	39.2	49	160	120.48	39.52
13	120	117.48	2.52	50	200	142.8	57.2
14	140	108.696	31.304	51	200	123.4	76.6
15	140	82.6	57.4	52	200	152.2	47.8
16	160	116	44	53	160	115.68	44.32
17	160	113.92	46.08	54	140	103.18	36.82
18	200	149.6	50.4	55	180	130.68	49.32
19	160	116	44	56	120	96.24	23.76
20	120	114.36	5.64	57	160	115.36	44.64
21	160	160	0	58	160	118.88	41.12
22	120	96.36	23.64	59	160	117.6	42.4
23	160	102.56	57.44	60	140	140	0
24	160	125.12	34.88	61	200	153	47
25	140	94.92	45.08	62	160	106.72	53.28
26	140	96.18	43.82	63	200	128.8	71.2
27	140	133.98	6.02	64	160	122.56	37.44
28	160	93.6	66.4	65	200	130.2	69.8
29	120	83.28	36.72	66	200	140.4	59.6
30	200	148.8	51.2	67	200	169.6	30.4
31	200	115	85	68	140	100.38	39.62
32	160	109.92	50.08	69	120	106.68	13.32
33	120	75.12	44.88	70	160	135.36	24.64
34	120	82.68	37.32	71	200	200	0
35	120	87.36	32.64	72	200	142	58
36	140	100.8	39.2	73	160	110.4	49.6
37	140	111.16	28.84	Mean	160.547	121.409	39.138

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

Table 3. The average amount of nitrogen fertilizer (Urea) obtained for the technical efficiency of wheat farming, for uncontrolled farms growing season 2017-2018

N	actual use of Urea fertilizer (kg/ha)	Urea fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)	N	actual use of Urea fertilizer (kg/ha)	Urea fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)
1	160	52.8	107.2	38	120	48.6	71.4
2	28	28	0	39	200	61.8	138.2
3	100	45.5	54.5	40	240	100.56	139.44
4	140	29.68	110.32	41	200	71.4	128.6
5	80	41.44	38.56	42	200	61.8	138.2
6	120	48.6	71.4	43	120	40.44	79.56
7	140	101.64	38.36	44	160	160	0
8	32	32	0	45	120	101.64	18.36
9	160	123.84	36.16	46	160	67.2	92.8
10	100	77.9	22.1	47	200	54.6	145.4
11	140	35.14	104.86	48	24	24	0
12	120	30.12	89.88	49	100	43.7	56.3
13	180	53.1	126.9	50	120	51	69
14	120	48.48	71.52	51	200	91.8	108.2
15	200	37.8	162.2	52	80	46.96	33.04
16	32	32	0	53	160	81.76	78.24
17	200	44.8	155.2	54	80	44.72	35.28
18	120	42.84	77.16	55	120	54.36	65.64
19	120	111.12	8.88	56	100	51.7	48.3
20	100	46.6	53.4	57	120	53.4	66.6
21	200	52.2	147.8	58	160	68.8	91.2
22	200	44.8	155.2	59	24	24	0
23	400	82.8	317.2	60	200	117.4	82.6
24	160	52.8	107.2	61	160	83.2	76.8
25	120	36.36	83.64	62	240	129.36	110.64
26	120	65.64	54.36	63	200	125	75
27	32	24.896	7.104	64	160	69.28	90.72
28	160	38.08	121.92	65	280	122.08	157.92
29	28	18.424	9.576	66	80	40.64	39.36
30	100	40.8	59.2	67	100	59.1	40.9
31	100	41.6	58.4	68	200	133.4	66.6
32	160	133.44	26.56	69	240	137.76	102.24
33	200	61.2	138.8	70	32	32	0
34	40	31.44	8.56	71	240	24	216
35	200	67.4	132.6	72	160	131.84	28.16
36	160	62.88	97.12	73	200	160.2	39.8
37	100	100	0	Mean	142.082	65.584	76.497

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

Table 4. The average amount of nitrogen fertilizer (Urea) obtained for the technical efficiency of wheat farming, for controlled farms for growing season 2017-2018.

N	actual use of Urea fertilizer (kg/ha)	Urea fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)	N	actual use of Urea fertilizer (kg/ha)	Urea fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)
1	200	130.6	69.4	38	200	156.2	43.8
2	220	143.22	76.78	39	220	174.9	45.1
3	200	112.6	87.4	40	240	240	0
4	240	213.36	26.64	41	220	211.2	8.8
5	160	149.76	10.24	42	200	139.6	60.4
6	180	139.5	40.5	43	240	153.84	86.16
7	180	146.52	33.48	44	160	125.28	34.72
8	160	124.16	35.84	45	180	142.92	37.08
9	180	176.94	3.06	46	240	202.56	37.44
10	160	145.28	14.72	47	140	79.24	60.76
11	160	108	52	48	200	116	84
12	200	160.8	39.2	49	200	150.6	49.4
13	160	156.64	3.36	50	220	157.08	62.92
14	160	124.224	35.776	51	240	148.08	91.92
15	200	118	82	52	220	167.42	52.58
16	160	116	44	53	200	144.6	55.4
17	200	142.4	57.6	54	200	147.4	52.6
18	200	149.6	50.4	55	200	145.2	54.8
19	220	159.5	60.5	56	160	128.32	31.68
20	220	209.66	10.34	57	160	115.36	44.64
21	120	120	0	58	200	148.6	51.4
22	180	144.54	35.46	59	200	147	53
23	160	102.56	57.44	60	120	120	0
24	180	140.76	39.24	61	220	168.3	51.7
25	200	135.6	64.4	62	240	160.08	79.92
26	160	109.92	50.08	63	200	128.8	71.2
27	160	153.12	6.88	64	200	153.2	46.8
28	240	140.4	99.6	65	240	156.24	83.76
29	160	111.04	48.96	66	160	112.32	47.68
30	200	148.8	51.2	67	200	169.6	30.4
31	160	92	68	68	160	114.72	45.28
32	200	137.4	62.6	69	200	177.8	22.2
33	200	125.2	74.8	70	220	186.12	33.88
34	160	110.24	49.76	71	240	240	0
35	120	87.36	32.64	72	220	156.2	63.8
36	200	144	56	73	180	124.2	55.8
37	160	127.04	32.96	Mean	191.232	144.735	46.496

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

Table 5. Average number of machinery working hours obtained for the technical efficiency of wheat farming, for uncontrolled farms for growing season 2017-2018

N	actual machinery working (hour/ha)	machinery working for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)	N	actual machinery working (hour/ha)	machinery working for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)
1	31.2	10.296	20.904	38	23.6	9.558	14.042
2	9.6	9.6	0	39	26	8.034	17.966
3	30.4	13.832	16.568	40	16.8	7.039	9.760
4	38.4	8.140	30.259	41	20.8	7.425	13.374
5	28	14.504	13.496	42	21.6	6.674	14.925
6	28	11.34	16.66	43	24	8.088	15.912
7	32	23.232	8.768	44	16.4	16.4	0
8	24	24	0	45	16.8	14.229	2.570
9	20.8	16.099	4.700	46	27.2	11.424	15.776
10	21.6	16.826	4.773	47	31.2	8.517	22.682
11	30.4	7.630	22.769	48	12.8	12.8	0
12	32.8	8.232	24.567	49	20.8	9.089	11.710
13	28.8	8.496	20.304	50	21.6	9.18	12.42
14	31.2	12.604	18.595	51	17.2	7.894	9.305
15	32	6.048	25.952	52	19.2	11.270	7.929
16	10.4	10.4	0	53	14.8	7.562	7.237
17	26.8	6.003	20.796	54	19.2	10.732	8.467
18	27.2	9.710	17.489	55	19.2	8.697	10.502
19	25.6	23.705	1.894	56	16.8	8.685	8.114
20	27.2	12.675	14.524	57	20.4	9.078	11.322
21	30	7.83	22.17	58	14.8	6.364	8.436
22	26.8	6.003	20.796	59	17.2	17.2	0
23	67.2	13.910	53.289	60	12	7.044	4.956
24	31.2	10.296	20.904	61	14.8	7.696	7.104
25	36.4	11.029	25.370	62	12.8	6.899	5.900
26	17.6	9.627	7.972	63	9.2	5.75	3.45
27	25.2	19.605	5.594	64	14.4	6.235	8.164
28	35.6	8.472	27.127	65	17.2	7.499	9.700
29	30	19.74	10.26	66	12.8	6.502	6.297
30	27.2	11.097	16.102	67	13.6	8.037	5.562
31	25.6	10.649	14.950	68	10.8	7.203	3.596
32	30	25.02	4.98	69	14	8.036	5.964
33	22.4	6.854	15.545	70	6	6	0
34	33.2	26.095	7.104	71	14.4	1.44	12.96
35	26.8	9.031	17.768	72	11.6	9.558	2.041
36	26	10.218	15.782	73	10.8	8.650	2.149
37	14.8	14.8	0	Mean	22.673	10.769	11.904

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

Table 6. Average number of machinery working hours obtained for the technical efficiency of wheat farming, for controlled farms for growing season 2017-2018

N	actual machinery working (hour/ha)	machinery working for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)	N	actual machinery working (hour/ha)	machinery working for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)
1	34.44	22.489	11.950	38	150	117.15	32.85
2	32.24	20.988	11.251	39	42.24	33.580	8.659
3	26.12	14.705	11.414	40	67.76	67.76	0
4	23.32	20.731	2.588	41	48.88	46.924	1.955
5	68.88	64.471	4.408	42	80	55.84	24.16
6	58.32	45.198	13.122	43	43.32	27.768	15.551
7	60	48.84	11.16	44	31.68	24.805	6.874
8	46.68	36.223	10.456	45	58.88	46.750	12.129
9	86.68	85.206	1.473	46	58.88	49.694	9.185
10	48.32	43.874	4.445	47	80	45.28	34.72
11	18.88	12.744	6.136	48	52.24	30.299	21.940
12	81.12	65.220	15.899	49	52.76	39.728	13.031
13	53.88	52.748	1.131	50	56.68	40.469	16.210
14	101.12	78.509	22.610	51	74.44	45.929	28.510
15	107.76	63.578	44.181	52	47.76	36.345	11.414
16	34.44	24.969	9.471	53	58.88	42.570	16.309
17	54.44	38.761	15.678	54	78.88	58.134	20.745
18	53.32	39.883	13.436	55	42.24	30.666	11.573
19	54.44	39.469	14.971	56	69.44	55.690	13.749
20	52.76	50.280	2.479	57	51.12	36.857	14.262
21	34.44	34.44	0	58	51.68	38.398	13.281
22	97.24	78.083	19.156	59	52.24	38.396	13.843
23	92.76	59.459	33.300	60	15	15	0
24	37.24	29.121	8.118	61	101.68	77.785	23.894
25	48.32	32.760	15.559	62	43.88	29.267	14.612
26	31.68	21.764	9.915	63	66.68	42.941	23.738
27	24.44	23.389	1.050	64	47.24	36.185	11.054
28	63.32	37.042	26.277	65	61.12	39.789	21.330
29	86.68	60.155	26.524	66	28.88	20.273	8.606
30	68.88	51.246	17.633	67	41.68	35.344	6.335
31	113.32	65.159	48.161	68	56.68	40.639	16.040
32	35.56	24.429	11.130	69	41.12	36.555	4.564
33	107.76	67.457	40.302	70	101.68	86.021	15.658
34	88.88	61.238	27.641	71	23.32	23.32	0
35	37.24	27.110	10.129	72	39.44	28.002	11.437
36	51.68	37.209	14.470	73	31.68	21.859	9.820
37	45.56	36.174	9.385	Mean	57.701	43.248	14.453

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

Table 7. Average human working hours obtained for the technical efficiency of wheat farming, for uncontrolled farms for growing season 2017-2018

N	actual Human working hours (hour/ha)	human working hours for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)	N	Human working hours (hour/ha)	human working hours for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)
1	41.6	13.728	27.872	38	32.8	13.284	19.516
2	14.4	14.4	0	39	46	14.214	31.786
3	40.4	18.382	22.018	40	31.2	13.072	18.127
4	61.6	13.059	48.540	41	26	9.282	16.718
5	32.8	16.990	15.809	42	50.4	15.573	34.826
6	38.8	15.714	23.086	43	28.4	9.570	18.829
7	44	31.944	12.056	44	19.2	19.2	0
8	21.6	21.6	0	45	14.8	12.535	2.264
9	25.6	19.814	5.785	46	29.6	12.432	17.168
10	26.8	20.877	5.922	47	41.2	11.247	29.952
11	56.8	14.256	42.543	48	20.8	20.8	0
12	44.8	11.244	33.555	49	34	14.858	19.142
13	38.8	11.446	27.354	50	23.2	9.86	13.34
14	43.2	17.452	25.747	51	25.6	11.750	13.849
15	52.8	9.979	42.820	52	29.6	17.375	12.224
16	18.8	18.8	0	53	18	9.198	8.802
17	50.4	11.289	39.110	54	26	14.534	11.466
18	50.8	18.135	32.664	55	25.2	11.415	13.784
19	20.8	19.260	1.539	56	24.8	12.821	11.978
20	48.8	22.740	26.059	57	23.2	10.324	12.876
21	40.8	10.648	30.151	58	22.8	9.804	12.996
22	46	10.304	35.696	59	13.6	13.6	0
23	56	11.592	44.408	60	30	17.61	12.39
24	41.6	13.728	27.872	61	18.4	9.568	8.832
25	57.2	17.331	39.868	62	18.8	10.133	8.666
26	20	10.94	9.06	63	18.4	11.5	6.9
27	21.6	16.804	4.795	64	22.8	9.872	12.927
28	46.8	11.138	35.661	65	22.4	9.766	12.633
29	42.8	28.162	14.637	66	25.6	13.004	12.595
30	48.8	19.910	28.889	67	16	9.456	6.544
31	38.8	16.140	22.659	68	36.8	24.545	12.254
32	45.6	38.030	7.569	69	18.4	10.561	7.838
33	31.2	9.547	21.652	70	10	10	0
34	20.8	16.348	4.451	71	24	2.4	21.6
35	25.6	8.627	16.972	72	22.4	18.457	3.942
36	34.4	13.519	20.880	73	10.8	8.650	2.149
37	12.4	12.4	0	Mean	31.578	14.500	17.077

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

Table 8. Average human working hours obtained for the technical efficiency of wheat farming, for controlled farms for growing season 2017-2018

N	actual Human working hours (hour/ha)	human working hours for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)	N	actual Human working hours (hour/ha)	human working hours for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)
1	19.04	12.433	6.606	38	9.44	7.372	2.067
2	19.6	12.759	6.840	39	12.76	10.144	2.615
3	14.96	8.422	6.537	40	6.2	6.2	0
4	11.44	10.170	1.269	41	6.2	5.952	0.248
5	9.64	9.023	0.616	42	13.96	9.744	4.215
6	16.88	13.082	3.798	43	19.6	12.563	7.036
7	13.16	10.712	2.447	44	9.64	7.548	2.091
8	13.96	10.832	3.127	45	10.04	7.971	2.068
9	9.84	9.672	0.167	46	14.24	12.018	2.221
10	6.04	5.484	0.555	47	19.4	10.980	8.419
11	19.04	12.852	6.188	48	19.24	11.159	8.080
12	18.84	15.147	3.692	49	14.24	10.722	3.517
13	7.16	7.009	0.150	50	16.4	11.709	4.690
14	16.88	13.105	3.774	51	17.04	10.513	6.526
15	18.28	10.785	7.494	52	16.4	12.480	3.919
16	17.24	12.499	4.741	53	19.04	13.765	5.274
17	19.6	13.955	5.644	54	13.56	9.993	3.566
18	9.44	7.0611	2.378	55	14.52	10.541	3.978
19	16.88	12.238	4.642	56	16.88	13.537	3.342
20	10.04	9.568	0.471	57	18.84	13.583	5.256
21	19.4	19.4	0	58	9.84	7.311	2.528
22	14.84	11.916	2.923	59	13.56	9.966	3.593
23	16.88	10.820	6.059	60	5.4	5.4	0
24	12.76	9.978	2.781	61	13.84	10.587	3.252
25	15.28	10.359	4.920	62	12.76	8.510	4.249
26	15.76	10.827	4.932	63	12.76	8.217	4.542
27	6.2	5.933	0.266	64	13.4	10.264	3.135
28	19.4	11.349	8.051	65	17.04	11.093	5.946
29	17.04	11.825	5.214	66	14.96	10.501	4.458
30	16.88	12.558	4.321	67	9.44	8.005	1.434
31	14.96	8.602	6.358	68	19.4	13.909	5.490
32	13.56	9.315	4.244	69	10.44	9.281	1.158
33	15.6	9.765	5.834	70	9.36	7.918	1.441
34	14.96	10.307	4.652	71	6.6	6.6	0
35	17.04	12.405	4.634	72	12	8.52	3.48
36	21.04	15.148	5.891	73	20	13.8	6.2
37	17.76	14.101	3.658	Mean	14.325	10.545	3.780

Source: Prepared by the researcher based on questionnaire data and technical efficiency analysis results.

Appendix C. Economic efficiency analysis

Table 1. Results of the estimation of economic efficiency for study sample of wheat farming for growing season 2017-2018 Data Envelope Analysis according to production function.

Uncontrolled farms				Controlled farms			
N	Technical efficiency	Allocative efficiency	Economic efficiency	N	Technical efficiency	Allocative efficiency	Economic efficiency
1	0.33	0.604	0.199	1	0.653	0.875	0.571
2	1	0.323	0.323	2	0.651	0.93	0.606
3	0.455	0.621	0.283	3	0.563	0.651	0.366
4	0.212	0.844	0.179	4	0.889	0.84	0.747
5	0.518	0.489	0.254	5	0.936	0.764	0.716
6	0.405	0.522	0.223	6	0.755	0.807	0.609
7	0.726	0.458	0.333	7	0.814	0.825	0.694
8	1	0.779	0.779	8	0.776	0.816	0.633
9	0.774	0.343	0.266	9	0.983	0.649	0.638
10	0.779	0.491	0.382	10	0.908	0.565	0.541
11	0.251	0.813	0.204	11	0.675	0.797	0.538
12	0.251	0.693	0.174	12	0.804	0.829	0.667
13	0.295	0.564	0.166	13	0.979	0.561	0.549
14	0.404	0.576	0.233	14	0.764	0.753	0.575
15	0.189	0.729	0.138	15	0.59	0.582	0.344
16	1	0.948	0.948	16	0.725	0.853	0.618
17	0.224	0.619	0.139	17	0.712	0.881	0.627
18	0.357	0.499	0.178	18	0.748	0.772	0.578
19	0.926	0.355	0.328	19	0.725	0.814	0.59
20	0.466	0.61	0.284	20	0.953	0.626	0.597
21	0.261	0.578	0.151	21	1	0.782	0.782
22	0.224	0.623	0.14	22	0.803	0.626	0.503
23	0.207	0.418	0.087	23	0.641	0.702	0.45
24	0.33	0.574	0.189	24	0.782	0.895	0.7
25	0.303	0.635	0.192	25	0.678	0.705	0.477
26	0.547	0.49	0.268	26	0.687	0.852	0.586
27	0.778	0.38	0.295	27	0.957	0.602	0.577
28	0.238	0.719	0.171	28	0.585	0.692	0.405
29	0.658	0.538	0.354	29	0.694	0.64	0.444
30	0.408	0.482	0.196	30	0.744	0.829	0.617
31	0.416	0.466	0.194	31	0.575	0.528	0.304
32	0.834	0.376	0.313	32	0.687	0.819	0.563
33	0.306	0.474	0.145	33	0.689	0.595	0.41
34	0.786	0.32	0.251	34	0.728	0.791	0.576
35	0.337	0.444	0.149	35	0.72	0.809	0.583
36	0.393	0.557	0.219	36	0.794	0.886	0.703
37	1	0.409	0.409	37	0.781	0.656	0.512
38	0.405	0.535	0.216	38	0.795	0.822	0.654
39	0.309	0.541	0.167	39	1	0.682	0.682
40	0.419	0.322	0.135	40	0.96	0.689	0.661
41	0.357	0.454	0.162	41	0.698	0.751	0.524
42	0.309	0.526	0.162	42	0.641	0.773	0.496
43	0.337	0.543	0.183	43	0.783	0.683	0.535
44	1	0.307	0.307	44	0.794	0.794	0.631
45	0.847	0.413	0.35	45	0.844	0.795	0.671
46	0.42	0.552	0.232	46	0.566	0.615	0.348
47	0.273	0.578	0.158	47	0.58	0.669	0.388
48	1	0.955	0.955	48	0.753	0.841	0.633
49	0.437	0.515	0.225	49	0.714	0.885	0.632
50	0.425	0.517	0.22	50	0.617	0.845	0.521
51	0.459	0.362	0.166	51	0.761	0.912	0.694
52	0.587	0.459	0.269	52	0.723	0.871	0.63
53	0.511	0.368	0.188	53	0.737	0.669	0.493

54	0.559	0.4	0.224	54	0.726	0.897	0.651
55	0.453	0.524	0.237	55	0.802	0.739	0.593
56	0.517	0.418	0.216	56	0.721	0.819	0.59
57	0.445	0.518	0.23	57	0.743	0.669	0.497
58	0.43	0.433	0.186	58	0.735	0.822	0.604
59	1	0.842	0.842	59	1	0.66	0.66
60	0.587	0.256	0.15	60	0.765	0.808	0.618
61	0.52	0.377	0.196	61	0.667	0.679	0.464
62	0.539	0.309	0.167	62	0.644	0.742	0.478
63	0.652	0.264	0.172	63	0.547	0.631	0.345
64	0.433	0.434	0.188	64	0.766	0.848	0.65
65	0.436	0.32	0.139	65	0.651	0.89	0.579
66	0.508	0.58	0.295	66	0.702	0.755	0.53
67	0.591	0.496	0.293	67	0.848	0.84	0.713
68	0.667	0.228	0.152	68	0.717	0.839	0.602
69	0.574	0.292	0.168	69	0.889	0.661	0.588
70	1	0.837	0.837	70	0.846	0.695	0.588
71	0.1	0.85	0.085	71	1	1	1
72	0.824	0.338	0.279	72	0.71	0.882	0.626
73	0.801	0.185	0.148	73	0.69	0.922	0.636
Mean	0.529	0.509	0.524	Mean	0.757	0.762	0.578

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

Appendix D. Estimating the amount of resources achieved for economic efficiency

Table 1. The average amount of compound fertilizer obtained for the economic efficiency of wheat farming, for uncontrolled farms for growing season 2017-2018

N	actual use of Compound fertilizer (kg/ha)	compound fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)	N	actual use of Compound fertilizer (kg/ha)	compound fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)
1	160	31.84	128.16	38	32	6.912	25.088
2	160	51.68	108.32	39	160	26.72	133.28
3	120	33.96	86.04	40	160	21.6	138.4
4	160	28.64	131.36	41	200	32.4	167.6
5	160	40.64	119.36	42	160	25.92	134.08
6	160	35.68	124.32	43	160	29.28	130.72
7	36	11.988	24.012	44	200	61.4	138.6
8	20	15.58	4.42	45	16	5.6	10.4
9	32	8.512	23.488	46	36	8.352	27.648
10	28	10.696	17.304	47	120	18.96	101.04
11	120	24.48	95.52	48	160	152.8	7.2
12	200	34.8	165.2	49	28	6.3	21.7
13	160	26.56	133.44	50	160	35.2	124.8
14	160	37.28	122.72	51	160	26.56	133.44
15	200	27.6	172.4	52	200	53.8	146.2
16	20	18.96	1.04	53	160	30.08	129.92
17	200	27.8	172.2	54	160	35.84	124.16
18	200	35.6	164.4	55	200	47.4	152.6
19	28	9.184	18.816	56	160	34.56	125.44
20	120	34.08	85.92	57	200	46	154
21	8	1.208	6.792	58	24	4.464	19.536
22	160	22.4	137.6	59	160	134.72	25.28
23	200	17.4	182.6	60	160	24	136
24	200	37.8	162.2	61	32	6.272	25.728
25	120	23.04	96.96	62	200	33.4	166.6
26	160	42.88	117.12	63	160	27.52	132.48
27	80	23.6	56.4	64	120	22.56	97.44
28	160	27.36	132.64	65	160	22.24	137.76
29	160	56.64	103.36	66	160	47.2	112.8
30	120	23.52	96.48	67	160	46.88	113.12
31	200	38.8	161.2	68	120	18.24	101.76
32	200	62.6	137.4	69	120	20.16	99.84
33	24	3.48	20.52	70	200	167.4	32.6
34	200	50.2	149.8	71	160	13.6	146.4
35	180	26.82	153.18	72	36	10.044	25.956
36	200	43.8	156.2	73	240	35.52	204.48
37	120	49.08	70.92	Mean	136.712	33.371	103.341

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

Table 2. The average amount of compound fertilizer obtained for the economic efficiency of wheat farming, for controlled farms for growing season 2017-2018

N	actual use of Compound fertilizer (kg/ha)	Compound fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)	N	actual use of Compound fertilizer (kg/ha)	Compound fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)
1	160	91.36	68.64	38	160	104.64	55.36
2	200	121.2	78.8	39	160	109.12	50.88
3	160	58.56	101.44	40	200	132.2	67.8
4	160	119.52	40.48	41	160	83.84	76.16
5	160	114.56	45.44	42	160	79.36	80.64
6	140	85.26	54.74	43	140	74.9	65.1
7	160	111.04	48.96	44	160	100.96	59.04
8	160	101.28	58.72	45	160	107.36	52.64
9	120	76.56	43.44	46	160	55.68	104.32
10	160	86.56	73.44	47	140	54.32	85.68
11	160	86.08	73.92	48	160	101.28	58.72
12	200	133.4	66.6	49	200	126.4	73.6
13	120	65.88	54.12	50	200	104.2	95.8
14	140	80.5	59.5	51	200	138.8	61.2
15	140	48.16	91.84	52	160	100.8	59.2
16	160	98.88	61.12	53	140	69.02	70.98
17	160	100.32	59.68	54	180	117.18	62.82
18	200	115.6	84.4	55	120	71.16	48.84
19	160	94.4	65.6	56	160	94.4	65.6
20	120	71.64	48.36	57	160	79.52	80.48
21	160	125.12	34.88	58	160	96.64	63.36
22	120	60.36	59.64	59	140	92.4	47.6
23	160	72	88	60	200	123.6	76.4
24	160	112	48	61	160	74.24	85.76
25	140	66.78	73.22	62	200	95.6	104.4
26	140	82.04	57.96	63	160	55.2	104.8
27	140	80.78	59.22	64	160	104	56
28	160	64.8	95.2	65	200	115.8	84.2
29	120	53.28	66.72	66	200	106	94
30	200	123.4	76.6	67	200	142.6	57.4
31	200	60.8	139.2	68	140	84.28	55.72
32	160	90.08	69.92	69	120	70.56	49.44
33	120	49.2	70.8	70	160	94.08	65.92
34	120	69.12	50.88	71	200	200	0
35	140	81.62	58.38	72	200	125.2	74.8
36	140	98.42	41.58	73	160	101.76	58.24
37	200	102.4	97.6	Mean	161.095	93.699	67.396

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

Table 3. The average amount of nitrogen fertilizer (Urea) obtained for the economic efficiency of wheat farming, for uncontrolled farms growing season 2017-2018

N	actual use of Urea fertilizer (kg/ha)	Urea fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)	N	actual use of Urea fertilizer (kg/ha)	Urea fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)
1	160	31.84	128.16	38	100	21.6	78.4
2	28	9.044	18.956	39	120	20.04	99.96
3	100	28.3	71.7	40	200	27	173
4	140	25.06	114.94	41	240	38.88	201.12
5	80	20.32	59.68	42	200	32.4	167.6
6	120	26.76	93.24	43	200	36.6	163.4
7	140	46.62	93.38	44	120	36.84	83.16
8	32	24.928	7.072	45	160	56	104
9	160	42.56	117.44	46	120	27.84	92.16
10	100	38.2	61.8	47	160	25.28	134.72
11	140	28.56	111.44	48	200	191	9
12	120	20.88	99.12	49	24	5.4	18.6
13	180	29.88	150.12	50	100	22	78
14	120	27.96	92.04	51	120	19.92	100.08
15	200	27.6	172.4	52	200	53.8	146.2
16	32	30.336	1.664	53	80	15.04	64.96
17	200	27.8	172.2	54	160	35.84	124.16
18	120	21.36	98.64	55	80	18.96	61.04
19	120	39.36	80.64	56	120	25.92	94.08
20	100	28.4	71.6	57	100	23	77
21	28	4.228	23.772	58	16	2.976	13.024
22	200	28	172	59	120	101.04	18.96
23	200	17.4	182.6	60	160	24	136
24	400	75.6	324.4	61	24	4.704	19.296
25	160	30.72	129.28	62	200	33.4	166.6
26	120	32.16	87.84	63	160	27.52	132.48
27	120	35.4	84.6	64	240	45.12	194.88
28	32	5.472	26.528	65	200	27.8	172.2
29	160	56.64	103.36	66	160	47.2	112.8
30	28	5.488	22.512	67	280	82.04	197.96
31	100	19.4	80.6	68	80	12.16	67.84
32	100	31.3	68.7	69	100	16.8	83.2
33	160	23.2	136.8	70	200	167.4	32.6
34	200	50.2	149.8	71	240	20.4	219.6
35	40	5.96	34.04	72	32	8.928	23.072
36	200	43.8	156.2	73	240	35.52	204.48
37	160	65.44	94.56	Mean	137.753	34.199	103.554

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

Table 4. The average amount of nitrogen fertilizer (Urea) obtained for the economic efficiency of wheat farming, for controlled farms for growing season 2017-2018.

N	actual use of Urea fertilizer (kg/ha)	Urea fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)	N	actual use of Urea fertilizer (kg/ha)	Urea fertilizer for efficiency (kg/ha)	Amount of surplus or deficit (kg/ha)
1	200	114.2	85.8	38	220	143.88	76.12
2	220	133.32	86.68	39	240	163.68	76.32
3	200	73.2	126.8	40	220	145.42	74.58
4	240	179.28	60.72	41	200	104.8	95.2
5	160	114.56	45.44	42	240	119.04	120.96
6	180	109.62	70.38	43	160	85.6	74.4
7	180	124.92	55.08	44	180	113.58	66.42
8	160	101.28	58.72	45	240	161.04	78.96
9	180	114.84	65.16	46	140	48.72	91.28
10	160	86.56	73.44	47	200	77.6	122.4
11	160	86.08	73.92	48	200	126.6	73.4
12	200	133.4	66.6	49	220	139.04	80.96
13	160	87.84	72.16	50	240	125.04	114.96
14	160	92	68	51	220	152.68	67.32
15	200	68.8	131.2	52	200	126	74
16	160	98.88	61.12	53	200	98.6	101.4
17	200	125.4	74.6	54	200	130.2	69.8
18	200	115.6	84.4	55	160	94.88	65.12
19	220	129.8	90.2	56	160	94.4	65.6
20	220	131.34	88.66	57	200	99.4	100.6
21	120	93.84	26.16	58	200	120.8	79.2
22	180	90.54	89.46	59	120	79.2	40.8
23	160	72	88	60	220	135.96	84.04
24	180	126	54	61	240	111.36	128.64
25	200	95.4	104.6	62	200	95.6	104.4
26	160	93.76	66.24	63	200	69	131
27	160	92.32	67.68	64	200	130	70
28	240	97.2	142.8	65	240	138.96	101.04
29	160	71.04	88.96	66	160	84.8	75.2
30	200	123.4	76.6	67	200	142.6	57.4
31	160	48.64	111.36	68	160	96.32	63.68
32	200	112.6	87.4	69	200	117.6	82.4
33	160	65.6	94.4	70	220	129.36	90.64
34	120	69.12	50.88	71	240	240	0
35	200	116.6	83.4	72	220	137.72	82.28
36	160	112.48	47.52	73	180	114.48	65.52
37	200	102.4	97.6	Mean	191.232	110.929	80.303

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

Table 5. Average number of machinery working hours obtained for the economic efficiency of wheat farming, for uncontrolled farms for growing season 2017-2018

N	actual machinery working (hour/ha)	machinery working for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)	N	actual machinery working (hour/ha)	machinery working for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)
1	31.2	6.208	24.991	38	14.8	3.196	11.603
2	9.6	3.100	6.499	39	23.6	3.941	19.658
3	30.4	8.603	21.796	40	26	3.51	22.49
4	38.4	6.873	31.526	41	16.8	2.721	14.078
5	28	7.112	20.888	42	20.8	3.369	17.430
6	28	6.244	21.756	43	21.6	3.952	17.647
7	28	9.324	18.676	44	24	7.368	16.632
8	28.8	22.435	6.364	45	16.4	5.74	10.66
9	20.8	5.532	15.267	46	16.8	3.897	12.902
10	21.6	8.251	13.348	47	27.2	4.297	22.902
11	30.4	6.201	24.198	48	31.2	29.796	1.404
12	32.8	5.707	27.092	49	12.8	2.88	9.92
13	28.8	4.780	24.019	50	10.8	2.376	8.424
14	31.2	7.269	23.930	51	20.8	3.452	17.347
15	32	4.416	27.584	52	17.2	4.626	12.573
16	10.4	9.859	0.540	53	19.2	3.609	15.590
17	26.8	3.725	23.074	54	14.8	3.315	11.484
18	27.2	4.841	22.358	55	19.2	4.550	14.649
19	25.6	8.396	17.203	56	19.2	4.147	15.052
20	27.2	7.724	19.475	57	16.8	3.864	12.936
21	12	1.812	10.188	58	14	2.604	11.396
22	30	4.2	25.8	59	20.4	17.176	3.223
23	26.8	2.331	24.468	60	14.8	2.22	12.58
24	67.2	12.700	54.499	61	13.6	2.665	10.934
25	31.2	5.990	25.209	62	12	2.004	9.996
26	36.4	9.755	26.644	63	14.8	2.545	12.254
27	17.6	5.192	12.408	64	12.8	2.406	10.393
28	14.4	2.462	11.937	65	9.2	1.278	7.921
29	35.6	12.602	22.997	66	14.4	4.248	10.152
30	10	1.96	8.04	67	17.2	5.039	12.160
31	27.2	5.276	21.923	68	12.8	1.945	10.854
32	25.6	8.012	17.587	69	13.6	2.284	11.315
33	22.8	3.306	19.494	70	10.8	9.039	1.760
34	22.4	5.622	16.777	71	14	1.19	12.81
35	15.2	2.264	12.935	72	6	1.674	4.326
36	26.8	5.869	20.930	73	10.8	1.598	9.201
37	26	10.63	15.366	Mean	21.720	5.631	16.088

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

Table 6. Average number of machinery working hours obtained for the economic efficiency of wheat farming, for controlled farms for growing season 2017-2018

N	actual machinery working (hour/ha)	machinery working for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)	N	actual machinery working (hour/ha)	machinery working for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)
1	8.61	4.916	3.693	38	10.56	6.906	3.653
2	8.06	4.884	3.175	39	16.94	11.553	5.386
3	6.53	2.389	4.140	40	12.22	8.077	4.142
4	5.83	4.355	1.474	41	20	10.48	9.52
5	17.22	12.329	4.890	42	10.83	5.371	5.458
6	14.58	8.879	5.700	43	7.92	4.237	3.682
7	15	10.41	4.59	44	14.72	9.288	5.431
8	11.67	7.387	4.282	45	14.72	9.877	4.842
9	21.67	13.825	7.844	46	20	6.96	13.04
10	12.08	6.535	5.544	47	13.06	5.067	7.992
11	4.72	2.539	2.180	48	13.19	8.349	4.840
12	20.28	13.526	6.753	49	14.17	8.955	5.214
13	13.47	7.395	6.074	50	18.61	9.695	8.914
14	25.28	14.536	10.744	51	11.94	8.286	3.653
15	26.94	9.267	17.672	52	14.72	9.273	5.446
16	8.61	5.320	3.289	53	19.72	9.721	9.998
17	13.61	8.533	5.076	54	10.56	6.874	3.685
18	13.33	7.704	5.625	55	17.36	10.294	7.065
19	13.61	8.029	5.580	56	12.78	7.540	5.239
20	13.19	7.874	5.315	57	12.92	6.421	6.498
21	8.61	6.733	1.876	58	13.06	7.888	5.171
22	24.31	12.227	12.082	59	3.75	2.475	1.275
23	23.19	10.435	12.754	60	25.42	15.709	9.710
24	9.31	6.517	2.793	61	10.97	5.090	5.879
25	12.08	5.762	6.317	62	16.67	7.968	8.701
26	7.92	4.641	3.278	63	22.78	7.859	14.920
27	6.11	3.525	2.584	64	11.81	7.676	4.133
28	15.83	6.411	9.418	65	15.28	8.847	6.432
29	21.67	9.621	12.048	66	7.22	3.826	3.393
30	17.22	10.624	6.595	67	10.42	7.429	2.990
31	28.33	8.612	19.717	68	14.17	8.530	5.639
32	8.89	5.005	3.884	69	10.28	6.044	4.235
33	22.22	9.110	13.109	70	25.42	14.946	10.473
34	9.31	5.362	3.9474	71	5.83	5.83	0
35	12.92	7.532	5.387	72	9.86	6.172	3.687
36	11.39	8.007	3.382	73	7.92	5.037	2.882
37	37.5	19.2	18.3	Mean	14.368	8.007	6.361

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

Table 7. Average human working hours obtained for the economic efficiency of wheat farming, for uncontrolled farms for growing season 2017-2018

N	actual Human working hours (hour/ha)	human working hours for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)	N	Actual Human working hours (hour/ha)	Human working hours for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)
1	41.6	8.278	33.321	38	12.4	2.678	9.721
2	14.4	4.651	9.748	39	32.8	5.477	27.322
3	40.4	11.433	28.966	40	46	6.21	39.79
4	61.6	11.026	50.573	41	31.2	5.054	26.145
5	32.8	8.331	24.468	42	26	4.212	21.788
6	38.8	8.652	30.147	43	50.4	9.223	41.176
7	33.6	11.188	22.411	44	28.4	8.718	19.681
8	21.6	16.826	4.773	45	19.2	6.72	12.48
9	25.6	6.809	18.790	46	14.8	3.433	11.366
10	26.8	10.237	16.562	47	29.6	4.676	24.923
11	56.8	11.587	45.212	48	41.2	39.346	1.854
12	44.8	7.795	37.004	49	20.8	4.68	16.12
13	38.8	6.440	32.359	50	34	7.48	26.52
14	43.2	10.065	33.134	51	23.2	3.851	19.348
15	52.8	7.286	45.513	52	25.6	6.886	18.713
16	18.8	17.822	0.977	53	29.6	5.564	24.035
17	50.4	7.005	43.394	54	18	4.032	13.968
18	50.8	9.042	41.757	55	26	6.162	19.838
19	20.8	6.822	13.977	56	25.2	5.443	19.756
20	48.8	13.859	34.940	57	24.8	5.704	19.096
21	20.8	3.140	17.659	58	22	4.092	17.908
22	40.8	5.712	35.088	59	23.2	19.534	3.665
23	46	4.002	41.998	60	22.8	3.42	19.38
24	56	10.584	45.416	61	13.6	2.665	10.934
25	41.6	7.987	33.612	62	30	5.01	24.99
26	57.2	15.329	41.870	63	18.4	3.164	15.235
27	20	5.9	14.1	64	18.8	3.534	15.265
28	21.6	3.693	17.906	65	18.4	2.557	15.842
29	46.8	16.567	30.232	66	22.8	6.726	16.074
30	29.6	5.801	23.798	67	22.4	6.563	15.836
31	48.8	9.467	39.332	68	25.6	3.891	21.708
32	38.8	12.144	26.655	69	16	2.688	13.312
33	29.6	4.292	25.308	70	36.8	30.801	5.998
34	31.2	7.831	23.368	71	18.4	1.564	16.836
35	20.8	3.099	17.700	72	10	2.79	7.21
36	25.6	5.606	19.993	73	10.8	1.598	9.201
37	34.4	14.069	20.330	Mean	30.986	7.897	23.088

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

Table 8. Average human working hours obtained for the economic efficiency of wheat farming, for controlled farms for growing season 2017-2018

N	Actual Human working hours (hour/ha)	Human working hours for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)	N	actual Human working hours (hour/ha)	Human working hours for efficiency (hour/ha)	Amount of surplus or deficit (hour/ha)
1	19.04	10.871	8.168	38	9.44	6.173	3.266
2	19.6	11.877	7.722	39	12.76	8.702	4.057
3	14.96	5.475	9.484	40	6.2	4.098	2.101
4	11.44	8.545	2.894	41	6.2	3.248	2.951
5	9.64	6.902	2.737	42	13.96	6.924	7.035
6	16.88	10.279	6.600	43	19.6	10.486	9.114
7	13.16	9.133	4.026	44	9.64	6.082	3.557
8	13.96	8.836	5.123	45	10.04	6.736	3.303
9	9.84	6.277	3.562	46	14.24	4.955	9.284
10	6.04	3.267	2.772	47	19.4	7.527	11.872
11	19.04	10.243	8.796	48	19.24	12.178	7.061
12	18.84	12.566	6.273	49	14.24	8.999	5.240
13	7.16	3.930	3.229	50	16.4	8.544	7.855
14	16.88	9.706	7.174	51	17.04	11.825	5.214
15	18.28	6.288	11.991	52	16.4	10.332	6.068
16	17.24	10.654	6.585	53	19.04	9.386	9.653
17	19.6	12.289	7.310	54	13.56	8.827	4.732
18	9.44	5.456	3.983	55	14.52	8.610	5.909
19	16.88	9.959	6.920	56	16.88	9.959	6.920
20	10.04	5.993	4.046	57	18.84	9.363	9.476
21	19.4	15.170	4.229	58	9.84	5.943	3.896
22	14.84	7.464	7.375	59	13.56	8.949	4.610
23	16.88	7.596	9.284	60	5.4	3.337	2.062
24	12.76	8.932	3.828	61	13.84	6.421	7.418
25	15.28	7.288	7.991	62	12.76	6.099	6.660
26	15.76	9.235	6.524	63	12.76	4.402	8.357
27	6.2	3.577	2.622	64	13.4	8.71	4.69
28	19.4	7.857	11.543	65	17.04	9.866	7.173
29	17.04	7.565	9.474	66	14.96	7.928	7.031
30	16.88	10.414	6.465	67	9.44	6.730	2.709
31	14.96	4.547	10.412	68	19.4	11.678	7.721
32	13.56	7.634	5.925	69	10.44	6.138	4.301
33	15.6	6.396	9.204	70	9.36	5.503	3.856
34	14.96	8.616	6.343	71	6.6	6.6	0
35	17.04	9.934	7.105	72	12	7.512	4.488
36	21.04	14.791	6.248	73	20	12.72	7.28
37	17.76	9.093	8.666	Mean	14.325	8.166	6.158

Source: Prepared by the researcher based on questionnaire data and economic efficiency analysis results.

CURRICULUM VITAE

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LANGUAGES

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