EFFICACY OF CROP MANAGEMENT PRACTICES ON PIGEONPEA (*Cajanus cajan* L. Millsp.) PRODUCTION IN SELECTED AREAS OF CENTRAL DRY ZONE

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A thesis submitted to the post-graduate committee of the Yezin Agricultural University as a partial fulfillment of the requirements for the degree of Master of Agricultural Science (Agronomy)

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The thesis attached hereto, entitled **"Efficacy of Crop Management Practices on Pigeonpea (*Cajanus cajan* L. Millsp.) Production in Selected Areas of Central Dry Zone"** was prepared under the direction of the supervisor of the candidate supervisory committee and has been approved by all members of that committee as a requirement for the **degree of Master of Agricultural Science.**

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DECLARATION OF ORIGINALITY

This thesis represents the original works of the author, except where otherwise stated. It has not been submitted previously for a degree at any other University.

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DEDICATED TO MY BELOVED PARENTS

U AYE WIN AND DAW HLA MYINT

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ABSTRACT

Field experiments were carried out to study the efficacy of crop management practices on pigeonpea production. The trials were conducted at Zaloke Research Farm, Monywa Township and Nyaung Oo Research Farm, Nyaung Oo Township from May 2017 to January 2018. Split-plot design with four replications was used in both experiments. Crop management practices including farmers' practice and improved practice were assigned in main plot factor. Four pigeonpea varieties such as Yezin-5, Yezin-8, Monywa Shwedingar and Nyaung Oo Shwedingar were allotted to subplot. In the improved practice Urea 31 kg ha^{-1}, T-super 62 kg ha^{-1} and Muriate of Potash 31 kg ha^{-1} were applied as basal and then four times of weeding at 30, 60, 90 and 120 DAS, one time of foliar fertilizer application at 30 DAS and four times of insecticide application at 60, 90, 120 and 150 DAS. Although basal application of compound fertilizer (15:15:15) 62 kg ha^{-1} and one time of intercultivation had done in farmers' practice, foliar fertilization and insecticide applications had excluded.

Yield and yield components of pigeonpea varieties were higher in improved practice than in farmers' practice in both study areas. In Zaloke Research Farm, among the tested varieties Nyaung Oo Shwedingar produced the higher seed yield (1267 kg ha^{-1}) while the lower seed yield was recorded from Yezin-8 (651 kg ha^{-1}). In Nyaung Oo Research Farm, among the varieties the higher seed yield was observed from Nyaung Oo Shwedingar (465 kg ha^{-1}) whereas the lower seed yield was recorded from Monywa Shwedingar (340 kg ha^{-1}). The higher total revenue and gross profit margin of pigeonpea were obtained under improved practice in both study areas. The interaction between crop management practices and varieties was detected for yield and yield components in both farm sites. There was a correlation between seed yield and other characters such as number of seeds pod^{-1}, number of pods plant^{-1} and plant height in both study areas.

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CHAPTER I
INTRODUCTION

Pulses are the dried edible seeds of certain plants in the legume family. They are vital source of protein and also rich in iron, iodine and essential amino acids. Deep rooting characteristics, ability to fix atmospheric nitrogen and enormous leaf fall make pulses an important component in cropping systems. Among pulses, pigeonpea (*Cajanus cajan* (L.) Millsp.) is the most important rainy season crop in Myanmar. It is a deep-rooted and drought-tolerant edible leguminous crop. Pigeonpea is the third most important pulse crop in Myanmar and grown entirely for export. In Myanmar, growing area of pigeonpea was 658,000 hectares with the average yield of 1.23 MT ha^{-1} and the total production of 812,000 MT (Ministry of Agriculture, Livestock and Irrigation [MOALI], 2018). Traditionally, long-duration (>200 days) pigeonpea varieties are cultivated under a wide range of cropping systems. It is mainly cultivated as an intercrop with cotton, groundnut, sesame, green gram and sunflower in Sagaing, Mandalay and Magway regions of Central Dry Zone of Myanmar (International Crops Research Institute for the Semi-Arid Tropics [ICRISAT], 2001).

Pigeonpea is one of the major grain legume crops in the tropical and subtropical regions of the world. It is an important source of protein and vitamin B. The protein content in split seeds is like to soybean and ranges from 21% to 28% (Phatak, Nadimpalli, Tiwari & Bhardwaj, 1993). A wide range of products can be produced from pigeonpea. Besides, pigeonpea's plant parts such as the dried seed, pods and immature seeds used as green vegetables, leaves and stems used for animal fodder and the dry stems used as fuel. It also increases soil fertility through nitrogen fixation as well as from the leaf fall and recycling of the nutrients (Snapp, Jones, Minja, Rusike & Silim, 2003). The crop grows well on a wide range of soil types from sandy to clay soils (Odeny, 2007). The crop can withstand low moisture condition and performs well in areas with less than 1000 mm of annual rainfall, depending on the distribution pattern. It is also considerably tolerable in saline soil conditions and these traits allow its cultivation in a wide range of environmental conditions and different cropping systems (Saxena, 2008).

The dry zone area of central Myanmar comprises of Magway, Mandalay and lower Sagaing regions and covers an area of 677,000 km^2 occupied with about 11 million people. It is characterized by low and unpredictable rainfall, land degradation and less diversified agricultural production systems with low inputs (ICRISAT, 2001). The low yield of pigeonpea is not only due to its cultivation on marginal land, but also because of insufficient and imbalance fertilization, uneven plant population, severe infestation of seasonal and perennial weeds, no adoption of intercultural operation, plant protection measures and climatic variability are major reasons to limiting the potential yield of pigeonpea. It also plays an important role in sustainable agriculture by enriching the soil through biological nitrogen fixation along with its deep root-system (Singh, Singh, Nayak, Yadav & Singh, 2016). This fact has made it more suitable for its cultivation even under rainfed condition. The main challenges for research and development are to bridge the gap between actual and attainable yield by enhancing farmers' access to quality inputs, improved technologies and information (Rao, Birthal, Bhagavatula & Bantilan, 2010). The total yield for pigeonpea grown in the production zones of India ranged from 550 to 770 kg ha^{-1} (Patole, Shinde & Yadav, 2008). Yields of pigeonpea vary widely relying on cultural practices, pest infestation, disease infection, predominant climatic conditions at flowering, and variety (EI Baradi, 1978).

Pigeonpea production is severely affected by several abiotic and biotic constraints, which cause low yields. In crop production, the final goal of any farmer is to get maximum yield per unit area. To obtain high yield, effective crop management practices appeared to be the main value. Crop management practices mean all the operations carried out on the farm, right from the start of the farming season to the end (Earnest, 1995). Crop production is met with many challenges among which are untimely planting, incorrect plant spacing, incorrect method of planting, poor sowing depth, delayed weeding, ineffective pests, and disease control, inappropriate use of fertilizers, untimely harvesting and above all usage of low yielding varieties of seeds. Proper management of nutrients and water is one of the major concerns for the successful cultivation of the crop. Poor management of water resources or irrigation has negative impact on both soil as well as the crop (Kar, Kumar & Martha, 2007).

Among the management practices, fertilization is the most important factor in determining the yield of pigeonpea. Low production of pigeonpea attributed to the fact that the crop is usually grown during the rainy season on marginal and less fertile soil. The use of micronutrients in pigeonpea is one of the ways to boost up the productivity and to improve the seed quality parameters. The application of nutrients through foliar spray at appropriate stages of growth becomes important for their utilization and better performance of the crop (Krishnaveni, Palchamy & Mahendran, 2004). Agronomic practice like plant population is known to affect crop environment, which influences the yield and yield components. Grain yield is the ultimate economic produce of the crop which is determined by grain weight, number of grains per unit land area as directed by management practices and its native genetic potential. Optimum population levels should be maintained to exploit maximum natural resources such as nutrient, sunlight, soil moisture and to ensure satisfactory yield (Sharifi, Sedghi & Gholipouri, 2009). Low seedling vigor makes weed control measure essential in pigeonpea cultivation during the critical period of first 40-60 DAS, during which weeds utilize plant nutrients and considerably reduce crop yield (Gurjar, Chauhan, Khandekar & Verma, 1987).

The production is constrained by the use of less productive land, water logging or dry spells during critical stages of crop growth, pest and disease problems and lack of drought-resistant varieties, high-yielding genotypes and suitable agronomic management. Moisture stress is one of the main restrictions in production of pigeonpea. Drought can cause more than half of the loss in the yield of pigeonpea (Roder, Maniphone & Keoboulapha, 1997). In a study of character association in pigeonpea observed that number of pods per plant is an important trait affecting final grain yield (Ganesamurthy & Dorairaj, 1990). Among the different agronomic practices, date of sowing, crop geometry (row spacing) and plant population for a particular cultivar and crop management practices plays an important role in determining yield in pigeonpea.

Improved crop management practices like tillage, planting time, planting density, quality seed, optimum seed rate, method of sowing, mulching, nutrient, and weed and irrigation offer greater opportunities in mitigating environmental and increased yield. Different agricultural practices can have significant influences on crop physiology and growth. Therefore, the present study was undertaken with the following objectives.

1) To compare the effect of crop management practices in pigeonpea production
2) To evaluate yield and agronomic performance of pigeonpea varieties
3) To observe the interaction effect of crop management practices and varieties on yield and yield components of pigeonpea

CHAPTER II
LITERATURE REVIEW

2.1 Important Role of Pigeonpea

Legumes are nutritious foods which can be substituted with animal proteins (Adebowale & Maliki, 2011). It contains 20% to 25% protein by weight, which is double the content of wheat and three times that of rice. It serves as a low-cost protein source to a large section of the people. Unlike other plant based food products, they contain little fat and cholesterol (Jukanti, Gaur, Gowda & Chibbar, 2012). Moreover, legume plant are also able to carry out a symbiotic association with rhizobia which fix atmospheric nitrogen (N) into plant available N. Some of the most consumed legume crops in the world are dry beans, peas, soya beans, groundnuts, chickpeas, pigeonpea, lintels, mung beans and cowpeas. Among them, pigeonpea (*Cajanus cajan* (L.) Millsp.) is one of the most important legume crops in agriculture. It is a good source of mineral such as phosphorus, magnesium, iron, calcium, sulphur and potassium but low in sodium (Kunyanga, Imungi & Vellingiri, 2013). The crop has its origin in India, and spread to Africa more than 4000 years ago (Van der Maesen, 1980). It has been cultivated for more than 3500 years in semi-arid and arid areas. Pigeonpea acts as a soil ameliorant and known to provide several benefits to the soil in which it is grown. It has the ability to bring minerals from deeper soil horizons to the surface and hence improving soil air circulation to the benefit of the accompanying crop (Rao, Dart & Sastry, 1983). The seeds, pods and the leaves are used by human and livestock being rich in nutrition and the crop generally enhances soil fertility through leaf litter and biological nitrogen fixation (Nandhini, Vimalendran, Latha, Sangamithra & Kalaiyarasan, 2015).

2.2 Pigeonpea Production in Myanmar

Pulses in Myanmar are produced both for export and domestic consumption, particularly in the Central Dry Zone which has the highest consumption of pulses on a daily basis. Among the crops mostly grown in Myanmar, pulses are the second most important crop after rice and have the highest potential for export and foreign income. Although pulses are very promising crops for export, pulse farmers are facing various problems and constraints, such as uncertain and sudden changes in weather conditions during the crop season, which subsequently cause serious pests and disease infestation, low-quality seed for cultivation, unstable domestic and export markets and sudden price fluctuations. At present, pulse yields targeted 1.6 to 2.5 t ha^{-1}, dependent on the kinds of pulse varieties, whereas the average actual yield, which farmers obtain at the farm level, is about 1.3 t ha^{-1} (Department of Agriculture [DOA], 2015).

Major exportable pulses are green gram, black gram and pigeonpea. Pigeonpea is the third most important pulse in Myanmar. It is a favorite crop of small holder farmers in the dry zone area due to its multiple uses and its role in sustainable agriculture. It is grown between May to June and is harvested between January to March. They are sown mainly in the Central Dry Zone, followed by Delta, Hilly, and Costal Zones, in that order. In Myanmar, about 90% of total production of pigeonpea is exported to India, Singapore, Indonesia, Malaysia, and UAE by oversea or border trade (Food and Agriculture Organization [FAO], 2016). Myanmar appears to be the only country where pigeonpea area and yields have increased. This has been mainly driven by the export market to neighboring India (Thaung & Choi, 2008).

2.3 Classification of Pigeonpea

Maturity duration is a very important factor that determines adaptation of varieties to different agro-climatic areas and cropping systems (Saxena, Mathews & Silim, 2001). Field duration of pigeonpea is controlled by temperature and sensitivity to photoperiod (Orr, Kabombo, Roth, Harris & Doyle, 2013). Pigeonpea have been classified into four major duration groups as shown in Table 2.1.

2.3.1 Extra-short duration (XSD)

Extra-short duration type of pigeonpea takes less than 100 days from planting to flowering. However, its growth or maturity may be delayed by cooler temperatures from 94 days at 23ºC to 175 days at 18ºC (Silim & Omanga, 2001). Extra-short duration pigeonpea type commonly has optimum population in subtropical environments to get high biomass production (Dahiya et al., 2002). It thrives best on well- drained loamy soils. Saline, alkaline, highly acidic (pH <5) and waterlogged soils are unfit for its cultivation as they adversely affect crop growth and nodulation (Johansen, Kumar, Rupela & Rego, 1990). Extra-short duration type has very slow initial growth rate and is highly susceptible to weed competition in the early stages of its growth. Due to shorter period of its life cycle as compared to short-duration and long-duration pigeonpea, it is more severely affected by weed competition. Weeds compete with the crop for incident light, nutrients, and moisture and also give shelter to various pests that attack pigeonpea also. Yield losses up to 30% have been observed in un-weeded crop (Singh, Chauhan, Johansen & Singh, 1996).

Table 2.1 Duration groups of pigeonpea and their maturity days

Duration group	Approximate days to maturity
1. Extra-short duration (XSD)	< 100
2. Short-duration (SD)	100 - 150
3. Medium-duration (MD)	151 - 180
4. Long-duration (LD)	>180

Source: Saxena et al., 2001

2.3.2 Short-duration (SD)

These varieties are insensitive to photoperiod and can be grown in frost-free areas (Saxena et al., 2001). Flowering in short-duration genotypes is also less sensitive to photoperiod and therefore they can bloom and mature even in the short summer (Kimani, 1990). Although the short-duration groups are more susceptible to pests, commercial farmers mostly cultivated these types of pigeonpea with the use of resources and production inputs because of its high maintenance (Joshi et al., 2010). Short duration genotypes develop a smaller root system than long-duration type (Singh & Oswalt, 1992).

2.3.3 Medium-duration (MD)

Medium-duration varieties are mostly intercropped and well produced in areas with warm temperatures which more often unsuitable for long-duration varieties. Medium-duration variety of maturity is delayed in areas away from the equator e.g., Malawi and Mozambique (Silim, Bramel, Akonaay, Mligo & Christiansen, 2005). Because medium-duration types are photosensitive, they always flower during short day periods (Saxena et al., 2001). Most of the medium-duration varieties are indeterminate varieties which flower within 110 days and mature within 160 days (Jones, Freeman & Monaco, 2002). These cultivars mostly adaptable in various types of agroecological zones, but they perform best at medium altitudes with 600 to 1500 m and with mean temperatures of 23ºC to 25ºC and rainfall of 400-1500 mm over two seasons (Snapp et al., 2003). There are now improved varieties of medium-duration in India and Myanmar, Kenya, Northern Tanzania and Uganda on-farm trials where in some areas farmers are already growing them in their farms (Joshi et al., 2010).

2.3.4 Long-duration (LD)

Long-duration varieties are mostly intercropped and grown in low-latitude and high-elevation areas near the equator. However, these varieties can be grown in areas away from the equator provided with warm temperature during the vegetative stage and cool during the reproductive stage (Silim et al., 2005). The long-duration varieties are also photoperiod sensitive and flower in short days (Saxena et al., 2001). In short rainy season areas, long-duration pigeonpea reserve soil moisture before the crop matures. But, in areas where there is little variation in temperature or day length and the crop will often not flower when it has reached 12 months or gone beyond that due to sudden change in temperature from warmer to cooler temperature (Jones et al., 2002). Early maturing of the crop is allowed by insensitive to cold temperature in the areas with 1400 m above sea level.

2.4 Important of Crop Management Practices for Increasing Pulse Production

The most potential technologies in pulse production include improved crop establishment and management practices, integrated soil fertility and pest management practices, which enhances not only the productivity and profitability but also warrants environmental and social sustainability besides nutritional security. Appropriate soil and crop management practices improved soil quality and crop productivity, through improved ecological and economical flexibility by reducing the need for additional agricultural land (Setter & Belford, 1990; Shaxson & Barber, 2003). Improved soil management can increase infiltration, reduce surface runoff, and additionally improved availability of water and nutrients to plants (Schmidt & Zemadim, 2015; Masunaga & Fong, 2018). Crop management can contribute to higher yields (Soomro, Rahman, Odhano, Gul & Tareen, 2009; Amare et al., 2013).

2.5 Some Important Agronomic Practices of Pigeonpea

2.5.1 Intercropping systems

Different pigeonpea cropping systems, such as crop rotation, intercropping and multiple cropping, have been regarded as the efficient methods in reducing the disease (Thurston, 2019). Although pigeonpea is integrated in several cropping systems, crop rotation system and intercropping are common practices where small-scale farmers used in growing pigeonpea (Odeny, 2007). Pigeonpea grown with these practices increased soil fertility through symbiotic nitrogen fixation which can also result in yield increase of intercropped crops (Adjei-Nsiah, 2012; Emefiene, Salaudeen & Yaroson, 2013). In intercropping with cowpea, pigeonpea acts as an excellent trap crop in pest control of the heteropteran species (Atachi & Rurema, 2006). Pigeonpea based cropping systems can be different from place to place. In Myanmar, in the dry zones and other upland rainfed areas, mixed cropping or intercropping of pigeonpea with sesame or peanut or other pulses are practiced (FAO, 2016).

Intercropping is a potentially beneficial system and shows substantial yield advantage over sole cropping as well as reduces risk (Singh, Singh & Maurya, 1992). Legume such as black gram, mung bean, soybean and cowpea were reported to be more remunerative intercrops with pigeonpea (Tomar, Sharma & Namdeo, 1984). In Nigeria, farmers cultivated pigeonpea as monocrop or in intercropping systems with maize, sorghum, yam, cassava, sweet potatoes and millet (Egbe & Vange, 2008).

Intercropping of pigeonpea with annual crops such as maize significantly improves the yield of the later and contributes to poverty reduction among smallholder farmers (Adjei-Nsiah, 2012). However to practice intercropping, it is important to use the cultivars with adapted maturity duration, structure and adequate biomass production in order not to reduce the yield of the associated crop (Saxena, 2006; Mula & Saxena, 2010). In the selection of compatible crops for intercropping systems, different growth pattern and their suitable planting geometries are the main features for the fact that the suitable selection helps to minimize inter and intra specific competitions for resources. Growing two legumes together helped not only in increasing productivity but also in achieving higher land equivalent ratio (Rao & Mittra, 1989). The most popular cropping system of pigeonpea in north India is intercropping with legumes (Ahlawat, Ali, Pal & Singh, 1986). It provides the whole yield of pigeonpea and an additional yield (0.4-0.5 t ha^{-1}) of the other legume such as mung bean, urad bean, cowpea and groundnut without additional inputs, except seed. Planting of one row of green gram between paired rows of pigeonpea proved superior to the pigeonpea monocropping (Kumar & Rana, 2007).

2.5.2 Plant arrangement and spacing

Among the various factors that influence the growth and yield of legume crops, spacing is considered important particularly although labor is restrictive factor. Wider spacing encouraged branching and number of pods per plant and pod filling, probably because the space and resources were sufficient for both vegetative and pod filling with in row spacing had a more significant effect than inter row spacing on the number of branches and pods bearing (Obuo & Okurut-Akol, 1995). Pigeonpea single row alternating with several rows of tall cereals were practiced in most traditional cereal and pigeonpea intercropping systems (Mergeai, Silim & Baudoin, 2001). In sorghum-pigeonpea, combination of two rows of pigeonpea spaced at 30 cm of plant spacing in 75 cm of row spacing gave the highest yield and also made the best use of land. The result indicated that intercropping was 24-75% more productive than mono-cropping (Kwena, 2018).

Naturally pigeonpea is an indeterminate photoperiod sensitive and perennial plant. The space available for an individual plant decides the significant of soil moisture, mineral nutrients and light energy used by the plant. The wider row spacing 75 cm, produced more branches per plant than narrow row spacing 50 cm (Ahlawat, Saraf & Singh, 1975). Furthermore, the interaction effects of population and genotypes on growth components (plant height, branches per plant and dry matter production) and net assimilation rate were significant. For pigeonpea seed yield, there were differed significantly due to different row spacing's during winter season (Srivastava, 1984).

2.5.3 Fertilizer application

Many investigators have reported that pigeonpea does not respond to fertilizers because their root system is so deep and extensive that it allows them to utilize available nutrients present deeply in the soil (Morton, 1976). Since the crop is a legume, it does not generally require N fertilization, except in some cases such as the conditions need to stimulate nodulation or to increase protein content where N is added in amounts of not more than 25 kg ha^{-1} (Manjhi, Chowdhury & Kavitkar, 1974). Addition of a high rate of N depresses N fixation of the plants (Dalal & Quilt, 1977). The amount of N treated had significant effect on plant height, branching and dry matter accumulation per plant (Singh, Saxena, Yadav & Sharma, 1980). Being a pulse crop, it utilizes the atmospheric nitrogen through symbiotic association. Yet for obtaining better yield a starter dose of nitrogen and adequate phosphorus are considered essential (Gupta, Katiyar & Singh, 1985). Phosphorus plays a vital role in the build-up and maintenance of soil productivity through its effects on legume growth as well as on the growth and survival of rhizobia (McLaughlin, Malik, Memon & Idris, 1990). Although, it is the second most critical plant nutrient overall, for pulses it is assumed as primary nutrients because of its important role in root proliferation and atmospheric nitrogen assimilation (Thiyagarajan, Backiyavathy, & Savithri, 2003). Besides, phosphorus is an essential nutrient in soils for healthy crop growth and high yields in pigeonpea. The highest seed yields were recorded (1755 kg ha^{-1}) when 60 kg P ha^{-1} was applied to pigeonpea and groundnut and it was also significantly higher by 5.3 and 1.6% than the control and 30 kg P ha^{-1}, respectively (Bheemasenrao, 2007).The response of grain legume to P application may vary as the soil P status changes. Sarkar, Shit and Chakraborty (1997) reported that seed yield of pigeonpea was highest with 90 kg P_2O_5 ha^{-1}. To produce economic return on soils deficient in P and K elements, moderate application of these elements can be expected (Rachie & Roberts, 1974). Manjhi (1971) reported that phosphorus application has favorable effect on number of pods $plant^{-1}$, grain weight and grain yield $plant^{-1}$. It was supported by Ram and Giri (1973) who observed significant improvement in the entire yield component up to 50 kg P_2O_5 ha^{-1}.

Potassium nutrition is related with grain quality including the protein content. Effective response to K application sets in when level of K fulfills the K hunger in soil (Ravichandran & Sriramachandrasekharan, 2011). The improved potassium supply enhances uptake of N and protein content in pulses (Tiwari, Pandey & Dubey, 2012). At 20 kg K_2O ha^{-1}, the maximum additional return was attained in pigeonpea, followed by pea, chickpea, lentil and urad bean (Yadav, Kumar & Singh, 1993). Fertilizer is a vital input in agriculture to boost the crop yields. Among the methods of fertilizer application, foliar nutrition is familiar as an important method of fertilization. Since foliar nutrients generally penetrate the leaf cuticle or stomata and enters the cells facilitating easy and fast utilization of nutrients. Foliar application of N at particular stage may solve the slow growth, nodule senescence and low seed yield of pulse without involving root absorption at critical stage (Latha & Nadanassababady, 2003). Ganapathy, Baradhan and Ramesh (2008) stated that foliar application was favorable in short duration pulse crops where the soil-applied fertilizer may not be fully available before the maturity of crops. Foliage applied macro and micronutrients at critical stages of the crop were effectively absorbed and translocated to the developing pods, producing more number of pods and better filling in soybean (Jayabal, Revathy & Saxena, 1999). The combined application of Rhizobium seed treatment and foliar application of N, P, K and chelated micronutrients (microsol) at 15, 30 and 45 DAS resulted in significant growth and yield characters (Manivannan, Thanunathan, Mayavaramban & Ramanathan, 2002).

2.5.4 Weed management

Weeds are a major constraint for legume production both in mechanized broad acre farming systems in advanced countries and labor-intensive smallholder farming systems in developing countries. As legume crop, many kinds of weed can infest pigeonpea fields. Pigeonpea is sensitive to weed competition as it grows relatively slow in the early growth stages. Weeds having high competitive ability compete for growth resources thereby affecting the productivity of pigeonpea. Hence, the productivity of pigeonpea is largely depends on a weed free condition particularly in early stages. Weeds can be controlled manually, mechanically, chemically or by using a combination of these methods. Pigeonpea can suppress the growth of weeds, but this is right only when the plants have extended a height of about 1 m. Therefore, effective weed control at early growth stages of the crop is important for high yield production. Other herbicides that have been used effectively are Ametryne, Chloramben, Diphenamid and Diquat (Akinola

& Whiteman, 1975). In a study, the cultural method (hand weeding) was found most effective in chickpea which noted the maximum seed yield and straw yield by 19.6 and 18.6% higher than un-weeded control (Pooniya et al., 2015). The mechanical weeding at 20 to 45 days after planting is effective in making a weed-free condition (Saxena & Yadav, 1975). Singh and Sekhon (2013) indicated that initial six weeks period is the critical period of crop weed competition, so weeds must be controlled during this period for obtaining higher grain yields of pigeonpea.

Most cultivated legumes crops are slow growing in the early stages and prone to weed competition. Competition from weeds may decrease grain legume yields by 25% to 40% (Pandey, Kamta, Prem & Singh, 1998). So, in situations where weeds emerge at the same time as crops, weeds should be controlled within 50 to 70 days after sowing to minimize grain yield loss (Diaz & Penaloza 1995). The initial 20 to 50 days after sowing (DAS) were found to be the most critical period for crop-weed competition in pigeonpea. The yield of pigeonpea was reduced from 32 to 65% due to severe competition of weeds with pigeonpea for its growth (Vaishya & Khan, 1989).

2.5.5 Pest and disease control

Pulses are susceptible to many insect pests and diseases. Insect pests are considered a serious problem for pigeonpea, both in the field and in storage. Among them, leafhoppers and pods borers are the most serious pests (EI Baradi, 1978). Kooner and Cheema (2006) reported that damage caused by insect pests as a major factor responsible for low crop yield where several insect pests attack from the seedling stage until harvest. Reed and Lateef (1990) revealed that the pod-sucking bugs (*Clavigralla* spp.) are one of the major insect pests of pigeonpea in the field. Pod borers caused 60 to 90% loss in the grain yield under favourable conditions (Sujithra & Chander, 2014). The pod fly, *Melanagromyza obtusa* alone causes a yield loss of 60 to 80% (Durairaj, 2006). A number of insecticides have been developed which help control pigeonpea field and storage attacks, such as DDT, Malathion, Dieldrin, Endrin, Dimethoate, Endosulfan, Disul foton, Mephospholan, Furadan, Thiodan and BHC. Yields of pigeonpea vary considerably among locations, cultivars, seasons and cropping systems. In most areas, insects are the most important yield constraint and the greatest cause of yield variation.

Wilt diseases caused by *Fusarium* spp. are important factors that limit yield and reduce quality of edible legumes. *Fusarium* wilt is a soil-borne disease and is regarded as a threat to pigeonpea production (Gwata, Silim & Mgonja, 2006). In chickpea crop, under favourable condition damage due to wilt disease cause 100% yield loss (Patra & Biswas, 2017). In pigeonpea, wilt is predominant in all major pigeonpea growing areas throughout the world and causes 30 to 100% yield loss (Biswas & Ghosh, 2016). Kimaro (2016) stated that a pigeonpea and sorghum mixed cropping or a pigeonpea, sorghum rotation reduces the *Fusarium* wilt infestation to below 20%. Low level of *Fusarium* wilt incidence (<10%) was observed in pigeonpea intercropped with cotton (Hillocks, Minja, Mwaga, Nahdy & Subrahmanyam, 2000). Integrated disease management is a combination of cultural practice, chemical control, biological control and the use of resistant varieties, and an effective management of the pigeonpea *Fusarium* wilt (Pande, Sharma, Avuthu & Telangre, 2012).

2.6 Climatic and Soil Requirements for Pigeonpea Cultivation

Pigeonpea can grow under widely different climatic and soil conditions from 30º N to 30º S latitudes (Akinola et al., 1975). It is a short-day plant whereby flowering is delayed by longer days (Botcha, Prattipati, Atluru & Jyothi, 2013). The crop grows well in hot and dry environment (Jones et al., 2002). It can grow well under semi-arid conditions with an average annual rainfall of about 625 mm; it is drought resistant, but it is intolerant of water-logged conditions and very sensitive to frost (El Baradi, 1978).

Drought is one of the most important environmental constraints limiting crop productivity in the tropics. Most pigeonpea cultivars are drought resistant and can give some grain yield during dry period, a rare phenomenon in many legumes. The ability of pigeonpea to withstand severe drought better than many legumes is due to its deep roots and osmotic adjustment in the leaves (Odeny, 2007). It has been found to grow throughout a six month dry season (Cook et al., 2005). However, flowering will be delayed and seed yields will decrease under long periods of drought (Mullen, Holland & Heuke, 2003). The crop thrives on a wide range of soils, providing the soils are not deficient in lime and are well-drained. Pulses are more sensitive to saline soil as compare to cereals and oilseeds. This might be due to the fact that, pulses accumulate excess salts that quickens the anthocyanin pigmention in leaves and stems which ultimately reduce germination and seedling establishment (Kumar, Solanki, Singh & Khan, 2016). On extremely acid soils, nodulation may be adversely affected, and on slightly alkaline soils (about pH 7.5) regrowth after the first bearing of pods may become extremely chlorotic and the plants may suffer die-back (El Baradi, 1978). The crop grows well in temperatures between 18ºC and 29ºC.

The crop is grown in rainfall areas and in day length environment of 11 to 14 hours and large differences in temperature is noticed due to variations in different altitude and latitude (Silim, Gwataa, Coeb & Omanga, 2007). Photoperiodic sensitivity is other restraint affecting pigeonpea production (Makelo, 2011). When the crop is grown in high latitude areas of more than 10° away from the equator it is sensitive to photoperiod and temperature. Plant height, vegetative biomass, phenology and grain yield are the crop parameters that are most affected by such condition. When a cultivar takes time to flower and mature it increases terminal drought which often occurs in Southern Africa (Gwata & Shimelis, 2013). The photoperiod and temperature effects on flowering and plant canopy development in pigeonpea make agronomists to choose cultivars that adapt and perform well to particular climatic situations (Silim et al., 2005). Crop sensitivity to different stress varies greatly, depending on the different growth stages of the crop such as the vegetative, reproductive, flowering and maturity stages (Sherlund, Barrett & Adesina, 2002). Moreover, Mar, Nomura, Takahashi, Ogata and Yabe (2018) observed that cloudy weather or rain at flowering and fruiting resulted in poor pod setting and seed filling and may lead to increased damage from pod borers. Cooper et al. (2009) used a modeling approach to predict that a temperature rise of 3ºC will reduce the current median yield of peanuts in Zimbabwe by 33% and pigeonpea in Kenya by 19%, largely as a result of shorter growing period and earlier maturity at high temperatures.

2.7 Constraints to High Grain Yield of Pigeonpea

Pigeonpea production is severely affected by several abiotic and biotic constraints, which cause low yields. The abiotic constraints include drought, salinity and water logging conditions (Chauhan, 1987). Other constraints include poor production practices, such as low plant densities, low soil fertility, insufficient weeding and inappropriate use of fungicides and herbicides and lack of high yielding varieties. The factors constraining the production of pigeonpea in Africa have been studied by (Odeny, 2007). It came out that there is a lack of improved varieties to meet farmers' needs. For instance, in transitional zone of Ghana, lack of early maturing cultivars was identified as one of the main challenges delaying the widespread cultivation of pigeonpea. Poor agronomic practices and lack of association of the pigeonpea market negatively affect the productivity and the capacity of farmers to sell their products at fair prices (Adjei-Nsiah, 2012). In Myanmar, the Central Dry Zone has limited rainfall, soil infertility, inadequate agricultural inputs as well as poor farming practices which have led to low agricultural productivity and income. The zone is also an area with high levels of soil erosion, mostly due to the lack of soil conservation measures in the past, causing a loss of organic matter and low water infiltration rate (FAO, 2016).

2.8 Nitrogen Fixation Ability of Pigeonpea

Nitrogen (N) is important and essential plant nutrition for plant growth and development whereby its deficiency has become a problem in agriculture (Egbe, Alhassan & Ijoyah, 2013). Pigeonpea has the ability to fix 235 kg ha^{-1} of N and produce more nitrogen per unit area from plant biomass than most of the legumes (Egbe & Bar-Anyam, 2011). Nitrogen fixation differs with duration types where by long duration (LD) genotypes can fix up to 200 kg N ha^{-1} over a period of 40 weeks and early maturing varieties fix 40 kg N ha^{-1} and it is further reported by (Murwa, 2013) that leaf drop alone can give up to 40 g of nitrogen. Biological nitrogen fixation from nodule is very essential for growth and yield of legumes and crop yield often remains low if the legumes do not have nodules in their roots (Dinh, Kaewpradit, Jogloy, Vorasoot & Patanothai, 2013). The cultivation of pigeonpea crop always contributes towards the improvement of soil structure and fertility through its deep penetrating roots, nitrogen fixation, and the release of soil-bound phosphorous and extensive dry leaf fall (Saxena, 2008).

Symbiotic association between a legume and rhizobia is vital for effective nitrate-fixation. Nitrogen influence from symbiotic Nitrate-fixation is important in Africa, whereby nitrogen is one of the most limiting nutrients for plant growth and crop yield (Murwa, 2013). Biological nitrogen fixation is important in intercropping system when nitrogen fertilizer is limited in the soil and organic matter status of that soil is low (Egbe, 2007). It is the only means which supply nitrogen to the plants in addition to valuable grain yield in poor-resource small scale farmers (Egbe & Kalu, 2009). Intercropping of legume and non-legume crops is important in nitrogen fixation and the transfer of nitrogen by legume to the other crop which is an important nutrient circulation in an agricultural ecosystem (Olujobi & Oyun, 2012).

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental Site

The experiments were conducted at Zaloke Research Farm, Monywa Township and Nyaung Oo Research Farm, Nyaung Oo Township from May 2017 to January 2018 under rainfed conditions. The study area, Monywa is located at 22° 6′N latitude, 95° 8′ E longitude and 81 meters elevation above the sea levels. Another study area, Nyaung Oo is located at 21° N latitude, 94° E longitude and 95 meters above the sea level.

3.2 Experimental Soil

A composite soil sample was collected from the experimental sites starting the experiment. Soil sample were analyzed at the laboratory of Soil Science, Water Utilization and Agricultural Engineering Division, Department of Agricultural Research (DAR). Physicochemical properties of soil for both experimental sites are shown in Table (3.1).

3.3 Experimental Design

The split plot design with four replications was used in this experiment. Individual plot size was 3 m × 6 m. Row spacing and plant spacing was 135 cm × 30 cm. Main plot included two crop management practices Farmers' Practice (FP) and Improved Practice (IP) and four varieties were assigned to subplots. Yezin-5, Yezin-8, Monywa Shwedingar and Nyaung Oo Shwedingar were used as tested varieties. Varietal characteristics of pigeonpea varieties are shown in Table (3.2).

3.4 Crop Management Practices for Pigeonpea

The improved practice for pigeonpea refers to the crop management practices recommended by DOA and farmers' practice represent those applied by most of the farmers in the study area (Table 3.3).

3.5 Cultural Operations for Pigeonpea

3.5.1 Field preparation

The preparation of field was done when the soil reached in good tilth. The experimental field was ploughed, harrowed and leveled for both improved and farmers' practices. Finally, the layout was done to meet the requirements of the experimental design.

3.5.2 Basal fertilizer application

Basal fertilizer was applied at the rate of 62 kg ha^{-1} (15:15:15) compound fertilizer for farmers' practice and 31 kg N ha^{-1} (as urea), 62 kg P_2O_5 ha^{-1} (as triple superphosphate) and 31 kg K_2O ha^{-1}(as muriate of potash) for improved practice at final land preparation.

3.5.3 Seed treatment, seed rate and sowing

The seeds were treated with carbofuran 2g kg^{-1} of seeds about one hour before sowing and sown by dropping them in opened furrows to 4 to 5 cm depth and spacing was provided as per the treatments and using a seed rate of 30 kg ha^{-1}.

3.5.4 Gap filling and thinning

Gap filling was undertaken ten days after sowing to maintain the optimal plant population. Thinning was done after 25 days after sowing to maintain required plant population retaining one healthy seedling at each hole.

3.5.5 Weed management

Weeding was done during the vegetative period in only one time of intercultivation for farmers' practice and four times; at 30, 60, 90 and 120 days after sowing for improved practice.

3.5.6 Foliar fertilizer and insecticide application

Foliar spray of nutrients (N, P_2O_5 and K_2O) was applied at the rate of 0.5 kg ha^{-1} for improved practice. Although no insecticide and foliar fertilizer was applied for farmers' practice, Cypermethrin was sprayed to reduce the infestation of pod borer and pod fly at the dosage of 500 cc ha^{-1} during the vegetative and reproductive period for improved practice (Table 3.3).

Table 3.1 Physicochemical properties of soil for both experimental sites

Characteristics	Contents	
	Zaloke Research Farm	**Nyaung Oo Research Farm**
Sand (%)	82	80
Silt (%)	8	7
Clay (%)	10	13
Texture class	Loamy Sand	Sandy Loam
pH	6.6	6.2
Available N (mg kg^{-1})	96 (high)	58 (low)
Available P (mg kg^{-1})	13 (medium)	5 (low)
Available K (mg kg^{-1})	180 (medium)	86 (low)

Source: Laboratory of Soil Science, Water Utilization and Agricultural Engineering Division, DAR.

Table 3.2 Varietal characteristics of pigeonpea varieties

Variety	**Days to maturity**	**Seed color**	**Seed yield (kg ha^{-1})**
Yezin-5	190-200	Reddish-yellow	654- 818 (20-25 bsk ac^{-1})
Yezin-8	200-210	Reddish-yellow	654- 818 (20-25 bsk ac^{-1})
Monywa Shwedingar	180-200	Reddish-yellow	752-818 (23-25bsk ac^{-1})
Nyaung Oo Shwedingar	190-200	Reddish-yellow	752-818 (23-25bsk ac^{-1})

Source: Zaloke Research Farm (DAR, 2017)

Table 3.3 Crop management factors of farmers' practice and improved practice in the experiments of Zaloke and Nyaung Oo research farms

Factors	Farmers' Practice	Improved Practice
Land preparation	Plowing - 1 time Harrowing - 2 times	Plowing- 1 time Harrowing- 2 times
Sowing time	June	June
Variety used	Yezin-5, Yezin-8, Monywa Shwedingar, Nyaung Oo Shwedingar	Yezin-5, Yezin-8, Monywa Shwedingar, Nyaung Oo Shwedingar
Basal fertilizer	15:15:15 (compound fertilizer) 62 kg ha^{-1})	Urea - 31 kg ha^{-1}, T-super - 62 kg ha^{-1}, Potash - 31 kg ha^{-1}
Seed treatment	Not practiced	Carbofuran 2g kg^{-1} of seeds
Weeding	1 time (intercultivation)	4 times (30, 60, 90 and 120 DAS)
Foliar fertilizer application	No spraying	N, P_2O_5, K_2O (0.5 kg ha^{-1}) 1 time 30 DAS
Insecticide application	No spraying	Cypermethrin 4.59 % (500cc ha^{-1}) 4 times (60, 90, 120 and 150 DAS)

Source: Department of Agriculture (DOA, 2016)

3.6 Data Collection

Agronomic characters yield and yield components were recorded based on the guideline outlined in descriptors for pigeonpea at harvest (International Board for Plant Genetic Resources [IBPGR], 1993).

3.6.1 Agronomic characters

Plant height was recorded from five sample plants which were randomly selected from each sample plot. The number of days to 50% flowering was determined by the number of days taken from sowing date to the 50% of the total number of plants plot^{-1} flowering out. For days to maturity, it was recorded 90% of the plant population reached physiological maturity.

3.6.2 Yield and yield components

3.6.2.1 Number of pods plant^{-1}

The total number of pods from the five selected sample plants and the average number of pods plant^{-1} was computed.

3.6.2.2 Number of seeds pod^{-1}

Twenty pods were randomly picked up from the sample plants and threshed to record the total number of seeds and average to record number of seeds pod^{-1}.

3.6.2.3 Hundred seed weight (g)

One hundred seeds had counted from the sample drawn randomly from each plot and weighed by electrical balance to record hundred seed weight in grams.

3.6.2.4 Seed yield plant^{-1} (g)

The seed yield obtained from the five sample plants had computed the average yield plant^{-1} in grams.

3.6.2.5 Seed yield (kg ha^{-1})

Pods from net plot area were threshed and the seed weight was recorded. From this, seed yield per hectare was computed.

3.7 Calculation

Increase yield (%) and gross margin were calculated by using the following formulae.

$$\text{Increase yield (\%)} = \frac{\text{Improved practice yield - Farmers' practice yield}}{\text{Improved practice yield}} \times 100$$

$$\text{GM} = \text{TR} - \text{TVC}$$

Where,

GM = Gross Margin

TR = Total Revenue

TVC = Total Variable Cost

(Emokaro & Law-Ogbomo, 2008)

3.8 Statistical Analysis

The data were subjected to analysis of variance (ANOVA) and significant differences between treatment means were determined by the least significant difference (LSD) test at $P \leq 0.05$ levels using the Statistix (Version 8).

CHAPTER IV
RESULTS AND DISCUSSION

Field experiments were conducted at Zaloke Research Farm, Monywa Township and Nyaung Oo Research Farm, Nyaung Oo Township from May 2017 to January 2018 and the experimental results are presented and discussed in this chapter.

4.1 Agronomic Characters

4.1.1 Plant height

Plant height of four pigeonpea varieties under different crop management practices are presented in Table (4.1). In Zaloke Research Farm, mean values of plant height were not significantly different between crop management practices. Although plant height was not significantly different under different crop management practices, mean values of plant height from improved practice (331.05 cm) was higher than that obtained from farmers' practice (314.50 cm) in Zaloke Research Farm. Among the tested varieties, Nyaung Oo Shwedingar had the highest plant height (328.72 cm) followed by Monywa Shwedingar (327.05 cm), Yezin-5 (318.27 cm) and Yezin-8 (317.04 cm).

In Nyaung Oo Research Farm, mean value of plant height was significantly different between crop management practices (Table 4.2). However, there was no significant difference in plant height among the varieties. The mean value of plant height from improved practice (170.13 cm) was higher than that observed from farmers' practice (140.44 cm). Among the tested varieties the highest plant height was found in Yezin-5 (163.63 cm) followed by Nyaung Oo Shwedingar (158.13 cm), Yezin-8 (156.25 cm) and Monywa Shwedingar (143.13 cm) respectively in Nyaung Oo Research Farm. The reason for difference in plant height under different crop management practices might be due to the presence of weed associated with the crop and severe competition throughout the crop growth. The main reason attributed to this was increased competition of weeds for light, nutrients and space especially in the initial stages of the crop. Bicer and Anlarsal (2004) revealed that the height of plant depend on sowing density, climate and environmental conditions besides genetically structure. Pundir, Reddy and Mengesha (1988) also stated that plant height is effected too much by environmental factors especially soil humidity and mineral content and also sowing density. Nagaraju and Kumar (2009) revealed that weed competition has the effect of progressively decreasing the plant height in pigeonpea. Interaction effect of crop management practices and varieties on plant height was not significantly observed in both study sites.

4.1.2 Days to 50% flowering

Mean values of days to 50% flowering of the tested pigeonpea varieties were not significantly different between crop management practices in both study areas (Table 4.1 and Table 4.2). However, the longer days to 50% flowering were observed from farmers' practice (171.13 days) and the shorter days to 50% flowering were recorded from improved practice (170.65 days) in Zaloke Research Farm. Among the tested varieties, the longest days to 50% flowering was detected from Yezin-8 (182.49 days) while the shortest days to 50% flowering was observed from Monywa Shwedingar (166.35 days). Similarly, in Nyaung Oo Research Farm, the greater number of days to 50% flowering was recorded from farmers' practice (169.03 days) and the smaller number of days to 50% flowering was obtained from improved practice (168.66 days). Among the tested varieties, the longest days to 50% flowering were observed from Yezin-8 (174.63 days) whereas the shortest days from Monywa Shwedingar (165.44 days).

In comparison between the farm sites, the statistical analysis indicated a significant variation in number of days to 50 % flowering due to different soil type, temperature and rainfall. The number of days to 50% flowering for any variety varied from site to site and season to season. The main causes of variation seem to be due to temperature, rainfall and altitude. High amounts of rainfall and lower temperature seem to increase the number of days to 50% flowering. Kimani, Benzioni and Ventura (1994) reported that number of days to 50% flowering was varied depending on the season and site. There was no interaction between crop management practices and pigeonpea varieties on days to 50% flowering in both farm sites. Days to flower initiation, plant height, secondary branches, number of seeds pod^{-1}, number of pods plant^{-1} and seed yield plant^{-1} were significantly varied by the genotype and environmental interaction (Kuchanur, Tembhurne & Patil, 2008).

Table 4.1 Effect of crop management practices on agronomic characters of pigeonpea varieties in Zaloke research farm

Treatments	Plant height (cm)	Days to 50% flowering	Days to maturity
Practice (a)			
Improved practice	331.05	170.65	201.78
Farmers' practice	314.50	171.13	201.50
$LSD_{0.05}$	18.09	0.98	1.01
Variety (b)			
Yezin-5	318.27	166.68 c	197.63 b
Yezin-8	317.04	182.49 a	213.50 a
Monywa Shwedingar	327.05	166.35 c	197.44 b
Nyaung Oo Shwedingar	328.72	168.04 b	198.00 b
$LSD_{0.05}$	14.41	0.74	1.32
Pr > F			
Practice	0.061	0.217	0.439
Variety	0.245	0.001	0.001
Practice × Variety	0.947	0.453	0.198
CV (a) %	4.98	0.51	0.44
CV (b) %	4.25	0.41	0.62

Means followed by the same letter within the column are not significantly different at 5% level

Table 4.2 Effect of crop management practices on agronomic characters of pigeonpea varieties in Nyaung Oo research farm

Treatments	**Plant height (cm)**	**Days to 50% flowering**	**Days to maturity**
Practice(a)			
Improved practice	170.13 a	168.66	201.00
Farmers' practice	140.44 b	169.03	200.38
$LSD_{0.05}$	21.32	0.48	4.43
Variety(b)			
Yezin-5	163.63	167.12 c	197.88 b
Yezin-8	156.25	174.63 a	210.69 a
Monywa Shwedingar	143.13	165.44 d	195.88 b
Nyaung Oo Shwedingar	158.13	168.18 b	198.31 b
$LSD_{0.05}$	24.68	0.71	3.06
Pr > F			
Practice	0.021	0.089	0.684
Variety	0.377	0.001	0.001
Practice × Variety	0.421	0.603	0.601
CV (a) %	12.20	0.25	1.96
CV (b) %	15.13	0.40	1.45

Means followed by the same letter within the column are not significantly different at 5% level

4.1.3 Days to maturity

The days to maturity of pigeonpea varieties were not significantly affected by crop management practices in both study areas (Table 4.1 and Table 4.2). However, there was significantly difference in days to maturity among the varieties in both study areas.

In Zaloke Research Farm, among the tested varieties the earliest days to maturity was observed in Monywa Shwedingar (197.44 days) whereas, the later days to maturity was recorded in Yezin-8 (213.50 days).

Similarly, in Nyaung Oo Research Farm, among the tested varieties the earliest days to maturity was recorded in Monywa Shwedingar (195.88 days) while the later days to maturity was obtained in Yezin-8 (210.69 days). Thus, the earlier days to 50% flowering and days to maturity had found in Monywa Shwedingar variety. It may be attributed to its varietal character and not related to crop management practices. There was no interaction between crop management practices and varieties on days to maturity in both study areas.

4.2 Yield and Yield Components

4.2.1 Seed yield

Crop management practices significantly affected on seed yield (kg ha^{-1}) of pigeonpea in both farm sites (Table 4.3 and Table 4.4). In Zaloke Research Farm, mean values of seed yield from improved practice (1313.10 kg ha^{-1}) were higher than that observed from farmers' practice (555.00 kg ha^{-1}). Among the tested varieties the highest seed yield was observed from Nyaung Oo Shwedingar (1267.00 kg ha^{-1}) whereas the lowest seed yield was obtained from Yezin-8 (651.00 kg ha^{-1}).

In Nyaung Oo Research Farm, mean values of seed yield from improved practice (531.15 kg ha^{-1}) were higher than that obtained from farmers' practice (267.47 kg ha^{-1}). Among the tested varieties the highest seed yield was observed from Nyaung Oo Shwedingar (465.38 kg ha^{-1}) while the lowest seed yield was recorded from Monywa Shwedingar (340.04 kg ha^{-1}).

The interaction between practices and varieties was observed on seed yield in Zaloke Research Farm (Figure 4.1). Among the tested varieties, Nyaung Oo Shwedingar shows the highest responsiveness to improved practice in both farm sites. In the improved practice, weed controls had done during 30 to 120 days after sowing with one time of foliar fertilizer application at 30 days after sowing and four times of insecticide application at 60 to 150 days after sowing. However, only one time of intercultivation was done in farmers' practice.

Table 4.3 Yield and yield components of pigeonpea varieties affected by different crop management practices in Zaloke research farm

Treatment	Seed yield (kg ha^{-1})	Seed yield plant^{-1} (g)	100 seed weight (g)	No. of seeds pod^{-1}	No. of pods plant^{-1}
Practice (a)					
Improved practice	1313.10 a	92.78 a	10.52	3.13 a	282.75 a
Farmers' practice	555.00 b	39.95 b	10.26	2.16 b	245.50 b
LSD $_{0.05}$	368.65	24.25	0.28	0.07	27.29
Variety (b)					
Yezin-5	842.20 bc	60.63 bc	9.68 b	2.59 b	257.50 ab
Yezin-8	651.00 c	46.03 c	12.36 a	2.55 b	239.13 b
Monywa Shwedingar	976.00 b	70.25 b	9.86 b	2.57 b	253.88 b
Nyaung Oo Shwedingar	1267.00 a	88.55 a	9.65 b	2.89 a	306.00 a
LSD $_{0.05}$	200.84	15.71	0.30	0.04	49.24
Pr > F					
Practice	0.001	0.001	0.059	0.001	0.022
Variety	0.001	0.001	0.001	0.001	0.050
Practice × Variety	0.001	0.001	0.552	0.001	0.162
CV (a) %	35.08	32.48	2.41	2.32	9.18
CV (b) %	20.47	22.53	2.75	1.61	17.75

Means followed by the same letter within the column are not significantly different at 5% level

Table 4.4 Yield and yield components of pigeonpea varieties affected by different crop management practices in Nyaung Oo research farm

Treatments	Seed yield (kg ha^{-1})	Seed yield plant^{-1} (g)	100 seed weight (g)	No. of seeds pod^{-1}	No. of pods plant^{-1}
Practice (a)					
Improved practice	531.15 a	23.51 a	10.45 a	3.13 a	163.94 a
Farmers' practice	267.47 b	12.03 b	9.81 b	2.65 b	130.69 b
$LSD_{0.05}$	74.47	3.65	0.42	0.25	15.16
Variety (b)					
Yezin-5	429.22 ab	19.31 ab	9.64 b	2.69 b	145.75
Yezin-8	362.60 bc	16.31 bc	11.63 a	2.74 b	136.25
Monywa Shwedingar	340.04 c	15.29 c	9.58 b	2.93 ab	139.25
Nyaung Oo Shwedingar	465.38 a	20.17 a	9.67 b	3.21 a	168.00
$LSD_{0.05}$	87.08	3.59	0.29	0.29	36.64
Pr>F					
Practice	0.001	0.001	0.024	0.001	0.001
Variety	0.025	0.030	0.001	0.001	0.288
Practice × Variety	0.058	0.093	0.032	0.853	0.608
CV (a) %	16.58	18.24	3.69	7.82	9.15
CV (b) %	20.76	19.22	2.75	9.67	23.68

Means followed by the same letter within the column are not significantly different at 5% level

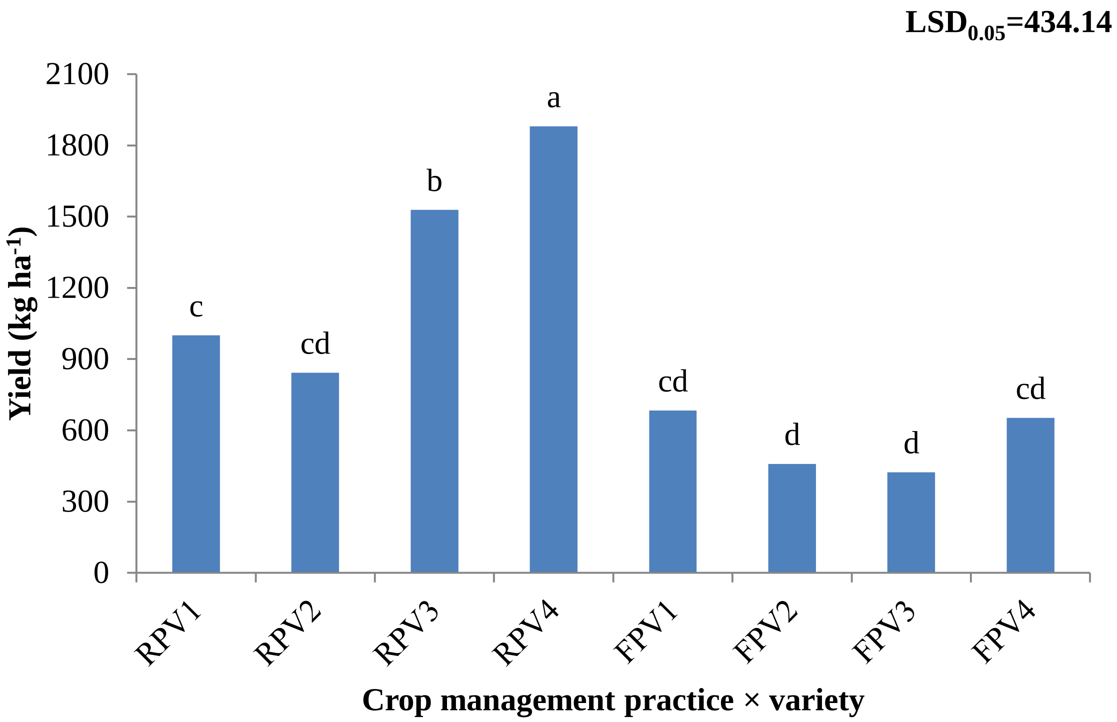

Figure 4.1 Interaction effects of crop management practices and varieties on yield in Zaloke research farm (IP= improved practice; FP= farmers' practice; V_1= Yezin-5; V_2= Yezin-8; V_3= Monywa Shwedingar; V_4= Nyaung Oo Shwedingar)

Thus, reduction of yield in farmers' practice may be attributed not enough weeding, lack of foliar fertilizer application and insecticide spraying during the crop growth period. Malik and Yadav (2014) also revealed that the presence of weeds throughout the growing season reduces potential yield of 68% in pigeonpea. In comparison among the combinations of practices and varieties, improved practice and Nyaung Oo Shwedingar showed the highest seed yield in both study areas. Therefore, Nyaung Oo Shwedingar is the most suitable one for the improved practice. For farmers' practice, Yezin-5 and Nyaung Oo Shwedingar varieties are the suitable varieties in both study areas.

4.2.2 Seed yield plant^{-1}

Seed yield is the function of number of pods plant^{-1}, number of seeds pod^{-1} and seed weight. Significant difference in seed yield plant^{-1} between crop management practices and among pigeonpea varieties were observed in both study areas (Table 4.3 and 4.4). In Zaloke Research Farm, mean values of seed yield plant^{-1} were increased markedly under improved practice which recorded (92.78 g) whereas the lower seed yield was observed from farmers' practice (39.95 g). Among the varieties, the highest seed yield plant^{-1} was observed from Nyaung Oo Shwedingar (88.55 g) whereas the lowest seed yield plant^{-1} was achieved from Yezin-8 (46.03 g).

In Nyaung Oo Research Farm, mean values of seed yield plant^{-1} from improved practice (23.51 g) was greater than that obtained from farmers' practice (12.03 g). Among the tested varieties the highest seed yield plant^{-1} was resulted from Nyaung Oo Shwedingar (20.17 g) whereas the lowest seed yield plant^{-1} was observed from Monywa Shwedingar (15.29 g). The reduction of seed yield plant^{-1} might be due to lesser number of seeds pod^{-1} and number of pods plant^{-1} in those varieties. The reduction of yield in farmers' practice may be attributed to weed infestation, more pest, and disease incidence during the crop growth period. Tomar, Sharma and Yadav (1999) reported that integrated nutrient management plus integrated pest management practices recorded higher grain yield of pigeonpea. There was significant interaction between practices and varieties on seed yield plant^{-1} in Zaloke Research Farm. Therefore, both practices and variety of pigeonpea should be considered to obtain higher number of seed pod^{-1} and seed yield plant^{-1}. Kaur and Saini (2018) reported that due to higher number of pods plant^{-1}, number of seeds pod^{-1} and 100 seed weight resulted into higher yield.

4.2.3 Hundred seed weight

Hundred seed weight was not significantly different under crop management practices in Zaloke Research Farm (Table 4.3). The mean values of hundred seed weight from improved practice (10.52 g) were higher than that recorded from farmers' practice (10.26 g). Among the tested varieties the highest hundred seed weight was observed from Yezin-8 (12.36 g) while the lowest hundred seed weight was recorded from Nyaung Oo Shwedingar (9.65 g). Being consistent with the varietal character of the large-seed size of the Yezin-8, the higher hundred seed weight was obtained by this variety in both farm sites.

In Nyaung Oo Research Farm, hundred seed weight was significantly different under crop management practices (Table 4.4). According to the result, mean values of hundred seed weight were higher in improved practice (10.45 g) than that obtained from farmers' practice (9.81 g). Among the tested varieties the highest hundred seed weight was recorded from Yezin-8 (11.63 g) while the lowest hundred seed weight was observed from Monywa Shwedingar (9.58 g). There was significant interaction of practices and varieties on hundred seed weight in Nyaung Oo Research Farm (Figure 4.3). It may due to different crop management practices especially weed control and spraying insecticide during the pod-filling stage. This variation indicates that results differ according to soil fertility status (Table 3.1), pest and disease incidence, weather conditions, where the amount of rainfall lower in Nyaung Oo was compared to Zaloke Research Farm (Appendix 1 and 2) during the crop season.

4.2.4 Number of seeds pod^{-1}

Number of seeds pods^{-1} is also another important factor that directly associates in exploiting potential yield recovery in pigeonpea. There were highly significant different in number of seeds pod^{-1} between crop management practices in both farm sites (Table 4.3 and 4.4). In Zaloke Research Farm, mean number of seeds pod^{-1} was observed from improved practice (3.13) whereas the lower number of seeds pod^{-1} was obtained from farmers' practice (2.16). Among the tested varieties the highest number of seeds pod^{-1} was obtained from Nyaung Oo Shwedingar (2.89) whereas the lowest number of seeds pod^{-1} was observed from Yezin-8 (2.55).

In Nyaung Oo Research Farm, mean values of number of seeds pod^{-1} from improved practice (3.13) was greater than that obtained from farmers' practice (2.65). Among the tested pigeonpea varieties the highest number of seeds pod^{-1} was observed from Nyaung Oo Shwedingar (3.21) while the lowest number of seeds pod^{-1} was obtained from Yezin-5 (2.69). Differences in number of seeds pod^{-1} might be due to different in crop management practices especially foliar fertilizer application and insecticide spraying during the pod-filling stage. Nair et al. (2017) reported that 21.00 to 38.50% pod and 12.29 to 19.87% seed damaged by pod fly and 5.50 to 12.50 % pod damaged by Lepidopterous pod borer.

There was interaction effect of practices and varieties by number of seeds pod^{-1} in Zaloke Research Farm (Figure 4.2). Therefore, it is necessary to consider both practices and varieties of pigeonpea to obtain higher number of seeds pod^{-1} and seed yield plant^{-1} for the specific location.

4.2.5 Number of pods plant^{-1}

Number of pods plant^{-1} of four pigeonpea varieties under different crop management practices are presented in Table (4.3) and (4.4). There were significant differences in number of pods plant^{-1} between improved and farmers' practices in both farm sites. In Zaloke Research Farm, higher mean values of number of pods plant^{-1} was achieved from improved practice (282.75) whereas the lower number of pods plant^{-1} was recorded from farmers' practice (245.50). Among the tested varieties, the highest number of pods plant^{-1} were produced from Nyaung Oo Shwedingar (306.00) whereas the lowest number of pods plant^{-1} was recorded from Yezin-8 (239.13). Differences in the number of pods plant^{-1} might be due to crop management practices especially weed control, foliar fertilizer application and spraying insecticide during the vegetative and pod-filling stages. Ananthi and Vanangamudi (2013) reported that foliar spray of 1% urea increased the number of pods significantly in greengram. Kumar, Dube and Chauhan (1999) stated that in soybean, number of pods plant^{-1} was greater with the foliar application of 50 ppm salicylic acid at 24 DAS.

In Nyaung Oo Research Farm, mean number of pods plant^{-1} was higher in improved practice (163.94) than that achieved from farmers' practice (130.69). Although, number of pods plant^{-1} was not significantly different among the tested varieties, Nyaung Oo Shwedingar showed maximum number of pods plant^{-1} in Nyaung Oo Research Farm. Sahoo and Senapati (2000) reported that among the insect species infesting pigeonpea, the pod borer complex is reported to reduce the yield up to 27.77%. There was no interaction effect of crop management practices and varieties were observed on number of pods plant^{-1} in both study areas.

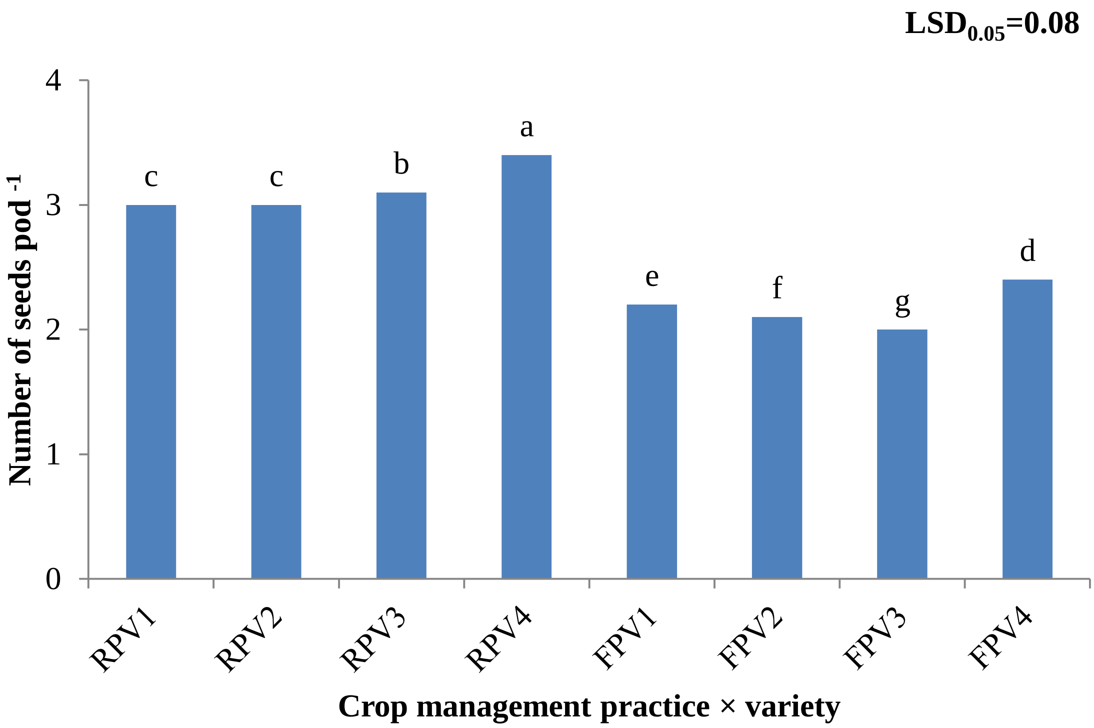

Figure 4.2 Interaction effects of crop management practices and varieties on number of seeds pod^{-1} in Zaloke research farm (IP= improved practice; FP= farmers' practice; V_1= Yezin-5; V_2= Yezin-8; V_3= Monywa Shwedingar; V_4= Nyaung Oo Shwedingar)

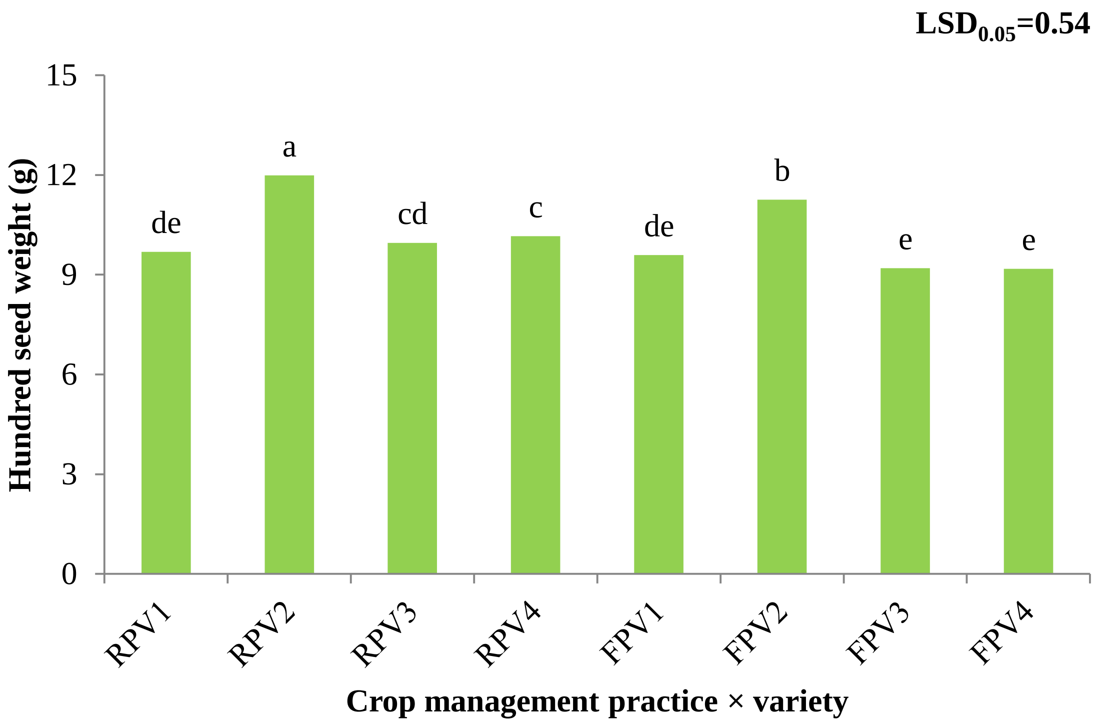

Figure 4.3 Interaction effects of crop management practices and varieties on hundred seed weight in Nyaung Oo research farm (IP= improved practice; FP= farmers' practice; V_1= Yezin-5; V_2= Yezin-8; V_3= Monywa Shwedingar; V_4= Nyaung Oo Shwedingar)

4.2.6 Correlation between yield, yield components and some agronomic characters of pigeonpea varieties

The correlation between yield, yield components and some agronomic characters are presented in Table (4.5) and (4.6). Seed yield was highly correlated with plant height, number of pods plant^{-1} and number of seeds pod^{-1}. Ganesamurthy et al., (1990) observed that positive and significant association of number of pods plant^{-1} with seed yield and it proves to be a vital character affecting final grain yield. The results of the study indicated that number of pods plant^{-1} and number of seeds pod^{-1} are important determining factors for seed yield of pigeonpea. Patel and Acharya (2011) also reported that seed yield was significantly and positively correlated with plant height, pods plant^{-1}, seeds pod^{-1} and hundred seed weight indicating the significance of these characters for seed yield in pigeonpea. Rekha, Prasanthi, Sekhar and Priya (2013) stated that an increase in plant height, number of primary branches, secondary branches and number of pods plant^{-1} would result in increased seed yield plant^{-1}. The significant positive relationships between yield and other parameters such as plant height, number of pods plant^{-1} and number of seeds pod^{-1} were observed in both study areas.

4.2.7 Economic performance of pigeonpea in Zaloke and Nyaung Oo research farms

The cost of cultivation, total revenue and gross margin from pigeonpea as affected by crop management practices and tested varieties were calculated and presented in Table (4.7). In Zaloke Research Farm, the highest total revenue and gross margin were observed from improved practice whereas the lowest total revenue and gross margin were obtained from farmers’ practice. Similarly, in Nyaung Oo Research Farm, the highest total revenue and gross margin were achieved from improved practice while the lowest total revenue and gross margin were observed from farmers’ practice. The percent seed yield increased in pigeonpea varieties in improved practice over farmers’ practice was high in Zaloke Research Farm (58%) and Nyaung Oo Research Farm (50%). Moreover, Nyaung Oo Shwedingar gave higher economic performance than other varieties in both study areas.

In comparison between the farm sites, the seed yield was higher in Zaloke Research Farm than that in the Nyaung Oo Research Farm. This may be attributed to the higher amount of rainfall, better availability of growth resources like moisture, soil nutrients which favored the development of crop in that area during the study period (Appendix 1 and 2). Therefore, the location specific crop management is required to bridge the gap in the potential and the demonstration yields (Vedna, Kumar, Kumar & Bhateria, 2007).

Table 4.5 Correlation between yield, yield components and some agronomic characters of pigeonpea varieties in Zaloke research farm

Character	Seed yield (kg ha^{-1})	100 seed wt. (g)	No. of seed pod^{-1}	No. of pods $plant^{-1}$	Plant height (cm)	Days to 50% flowering	Days to maturity
Seed yield (kg ha^{-1})	1						
100 seed wt. (g)	0.235	1					
No. of seeds pod^{-1}	0.830 **	0.006	1				
No. of pods $plant^{-1}$	0.659 **	0.231	0.464 **	1			
Plant height (cm)	0.581 **	0.091	0.528 **	0.463 **	1		
Days to 50% flowering	0.097	0.030	-0.054	-0.030	-0.014	1	
Days to maturity	0.150	0.061	0.066	-0.003	0.042	0.980**	1

****, s**ignificant difference at 1% level

Table 4.6 Correlation between yield, yield components and some agronomic characters of pigeonpea varieties in Nyaung Oo research farm

Character	**Seed yield ($kg\ ha^{-1}$)**	**100 seed wt. (g)**	**No. of seeds pod^{-1}**	**No. of pods $plant^{-1}$**	**Plant height (cm)**	**Days to 50% flowering**	**Days to maturity**
Seed yield ($kg\ ha^{-1}$)	1						
100 seed wt. (g)	0.155	1					
No. of seeds pod^{-1}	0.568*	0.153	1				
No. of pods $plant^{-1}$	0.609*	0.014	0.457**	1			
Plant height (cm)	0.524 **	0.223	0.122	0.439**	1		
Days to 50% flowering	-0.137	0.032	-0.215	-0.185	0.0085	1	
Days to maturity	-0.116	0.063	-0.201	-0.125	0.029	0.915**	1

***, ****Significant difference at 5% and 1% level respectively,

4.2.8 Economic performance of pigeonpea varieties under crop management practices

Different crop management practices affect the various total variable costs due to the additional cost for applying different management practices (Table 4.8 and 4.9). Yield increase of improved practice over farmers' practice ranged from 32% to 72% in Zaloke Research Farm and 41% to 61% in Nyaung Oo Research Farm among the tested varieties in this study. The higher total revenue and gross margin were observed from Nyaung Oo Shwedingar variety under the improved practice in both study areas. Under farmers' practice, the highest total revenue and gross margin were observed from Yezin-5 in Zaloke Research Farm. According to the result, under farmers' practice, all of the tested varieties had not obtained profit in Nyaung Oo Research Farm. Because of the different weather conditions due to different location especially soil type (Table 3.1), total rainfall lower in Nyaung Oo Research Farm was compared to Zaloke Research Farm (Appendix 1 and 2). The higher seed yield in improved practice might be due to weed management, foliar fertilizer application and pest and disease management. Singh et al., (1980) also revealed that the first 45 days are most critical for crop-weed competition in pigeonpea and control of weeds during this period offered maximum benefit to the crop. The low yields have been attributed mainly to lack of suitable varieties, several diseases that reduce their productivity, insect damage, moisture stress, poor soil fertility and social economic factors (Kimani, 1987).

Table 4.7 Economic performance of pigeonpea varieties under improved practice and farmers' practice in Zaloke and Nyaung Oo research farms

Practices	Yield (kg ha^{-1})	Increased in yield over FP (%)	Total variable cost (Ks. ha^{-1})	Total revenue (Ks. ha^{-1})	Gross margin (Ks. ha^{-1})
Zaloke research farm					
Improved practice	1313.10	58	411000	1043915	632915
Farmers' practice	555.00		307000	441225	134225
Nyaung Oo research farm					
Improved practice	531.15	50	420000	422264	2264
Farmers' practice	267.47		312000	212639	- 99361

FP = Farmers' Practice

Table 4.8 Economic performance and increased in yield over farmers' practice of pigeonpea varieties under crop management practices in Zaloke research farm

Variety	Yield (kg ha^{-1})	Increased in yield over FP (%)	Total variable cost (Ks. ha^{-1})	Total revenue (Ks. ha^{-1})	Gross margin (Ks. ha^{-1})
Improved Practice					
Yezin-5	1000.30	32	411000	795239	384239
Yezin-8	842.90	46	411000	670106	259106
Monywa Shwedingar	1528.30	72	411000	1214999	803999
Nyaung Oo Shwedingar	1881.00	65	411000	1495395	1084395
Farmers' Practice					
Yezin-5	684.10		307000	543859	236859
Yezin-8	459.10		307000	364985	57985
Monywa Shwedingar	423.80		307000	336921	29921
Nyaung Oo Shwedingar	652.90		307000	519056	212056

FP = Farmers' Practice

Table 4.9 Economic performance and increased in yield over farmers' practice of pigeonpea varieties under crop management practices in Nyaung Oo research farm

Variety	Yield (kg ha^{-1})	Increased in yield over FP (%)	Total variable cost (Ks. ha^{-1})	Total revenue (Ks. ha^{-1})	Gross margin (Ks. ha^{-1})
Improved Practice					
Yezin-5	550.11	44	420,000	437338	17338
Yezin-8	457.06	41	420,000	363363	-56637
Monywa Shwedingar	446.06	48	420,000	354618	-65382
Nyaung Oo Shwedingar	671.38	61	420,000	533747	113747
Farmers' Practice					
Yezin-5	308.33		312000	245122	-66878
Yezin-8	268.14		312000	213171	-98829
Monywa Shwedingar	234.03		312000	186054	-125946
Nyaung Oo Shwedingar	259.39		312000	206215	-105785

FP = Farmers' Practice

CHAPTER V
CONCLUSION

The two crop management practices showed significantly difference in yield, yield components and some agronomic characters of pigeonpea in both farm sites. The higher mean values of seed yield were observed under the improved crop management practice and the highest seed yield was observed from Nyaung Oo Shwedingar variety which was significantly different from other varieties in both farm sites. The higher seed yield of this variety may be due to a greater number of pods plant^{-1}, number of seeds pod^{-1} and seed yield plant^{-1}.

There was a significant interaction between practices and varieties in terms of seed yield and the combination of improved practices and Nyaung Oo Shwedingar variety gave the highest seed yield of pigeonpea in both study areas. Therefore, it is necessary to select the suitable pigeonpea variety for improved practice for the specific location to obtain higher seed yield.

In comparison of the experimental sites, the seed yield and yield correlated traits were higher in Zaloke Research Farm than those in the Nyaung Oo Research Farm. The greater yield increased percent of pigeonpea had observed under improved practice than farmers' practice. Therefore, site-specific crop management practice is necessary to increase pigeonpea production in those areas. The improved practice gave the higher gross margin than farmers' practice in both study areas. It may due to higher yield obtained under improved practice as compared to farmers' practice. Therefore, the results suggested that the productivity and profitability of pigeonpea can enhance by accepting the improved agronomic practices in both study areas.

Furthermore, it is necessary to encourage pigeonpea farmers to adopt improved agricultural practices for increasing production and income as well. The proper strategy will be necessary to exclude the limitations of pigeonpea crop management factors by upgrading the research and extension activities.

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APPENDICES

Appendix 1 Weather data during experimental period in 2017

Month	Total Rainfall (mm)	Temperature (ºC)		Average Temperature (ºC)
		Maximum	Minimum	
January	-	30	15	22
February	-	34	17	26
March	17	35	20	27
April	32	38	23	30
May	214	38	26	32
June	16	35	27	31
July	187	35	26	30
August	134	34	26	30
September	108	36	23	30
October	182	36	22	29
November	21	32	15	24
December	2	32	15	24

Source: Zaloke Research Farm, Monywa Township

Appendix 2 Weather data during experimental period in 2017

Month	Total Rainfall (mm)	Temperature (ºC)		Average Temperature (ºC)
		Maximum	Minimum	
January	-	35	11	23
February	-	38	13	26
March	8	41	15	28
April	102	45	20	32
May	156	42	24	33
June	16	37	26	31
July	72	36	24	30
August	7	38	25	31
September	138	38	24	31
October	170	38	20	29
November	21	36	14	25
December	9	33	12	22

Source: Nyaung Oo Research Farm, Nyaung Oo Township

Appendix 3 Preparation of experimental layout

Appendix 4 Seeding of pigeonpea varieties in furrows

Appendix 5 General view of experimental site at Zaloke research farm

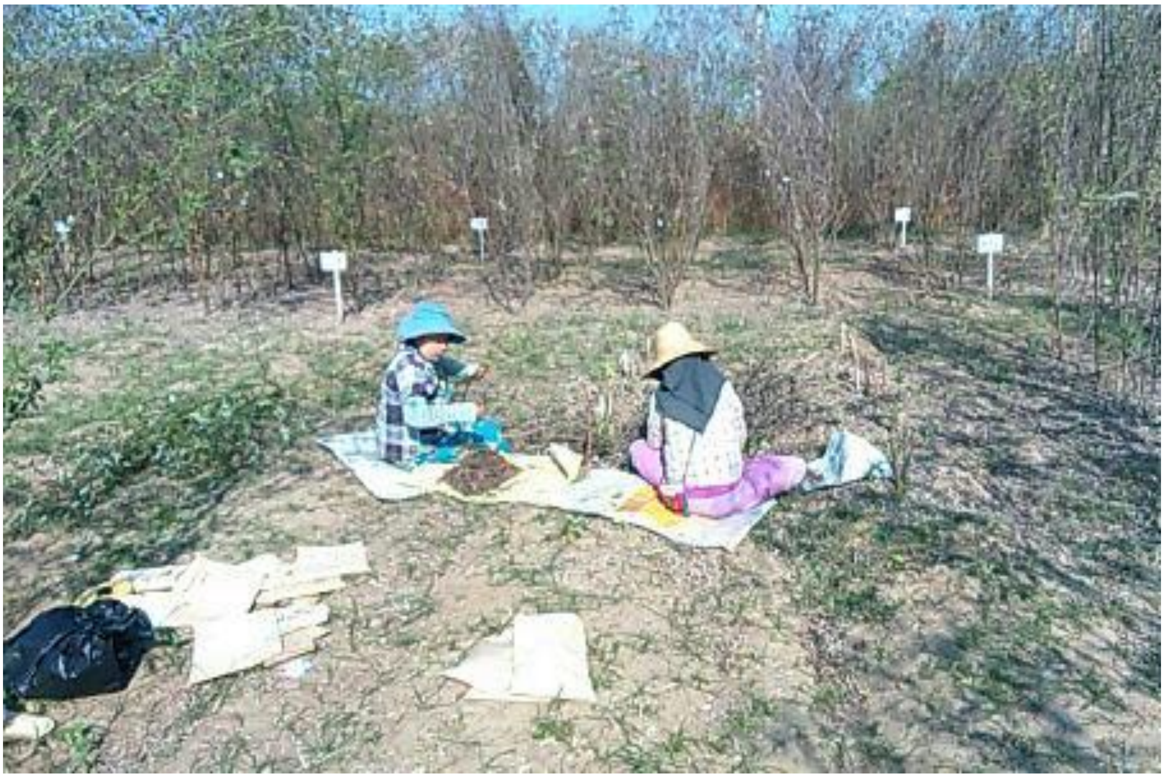
Appendix 6 General view of experimental site at Nyaung Oo research farm

Appendix 7 Photo record with farmers participated in the field day for improved practice and farmers' practice on field day at Zaloke research farm

Appendix 8 Observing plant characteristics by the farmers

Appendix 9 Discussion for improved practice and farmers' practice on field day at Zaloke research farm

Appendix 10 Harvesting and data collection at Zaloke research farm



Appendix 11 Harvesting and data collection at Nyaung Oo research farm

Appendix 12 Measuring for yield and yield components of pigeonpea obtained from Zaloke and Nyaung Oo research farms at the Department of Agronomy