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Companion Crops for Intercropping with Onion Production in the Dry Season at Fogera District of South Gondar Zone in Ethiopia

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Abstract: *Onion is a major cash crop mainly produced in the off season using irrigation in Fogera and its surrounding districts of South Gondar zone in Ethiopia. This system of production and marketing is now at a high risk due to repeated monoculture, and harvesting and supply of onion bulbs to the market at a similar time by many farmers. This high supply at a season which peaks towards the end of dry season causes a market glut and falling prices. Furthermore, build up of disease and other insect pest, and dwindling soil fertility are attributable to reduction in productivity and quality of onion bulbs. Targeting to contribute towards minimizing production and marketing risks thereby raising income of growers, this study on intercropping was therefore initiated to identify appropriate companion (second) crop with onion production in the off season using irrigation.*

Land equivalent ratio in 2016/17 revealed that the highest yield was obtained from intercropping onion with Dill followed by rape seed, kale and black cumin, while the highest yield in 2017/18 was from intercropping onion with lentil, rape seed, kale and linseed. In general, intercropping onion with both crops considered in this study, except fenugreek, was found more advantageous than sole cropping. Intercropping onion with rapeseed, dill and kale was found more efficient than other intercrops. However, choice for one or two best intercrops may depend on scale of production, the market demand and sustainability of system. Rape seed and kale are used for fresh consumption and require immediate marketing and may not be suitable to large scale production. These kale and rapeseed however can be used as an early income source for they are harvested early. On the other hand, black cumin, linseed, lentil and dill are produced for their grain and there is a flexibility for long storage until good price in the market is secured. Other criteria to be considered may include sustainability of the production system via minimizing build up of diseases and insects, and replenishing soil fertility.

Keywords: *Double harvest, legumes, main season, production risk, sustainability, vegetables.*

1. INTRODUCTION

Fogera and its surrounding districts and zones, particularly south and north Gondar zones and Bahir zuria are suitable for the cultivation of various kinds of horticultural crops both under rain fed and in the off season using irrigation**.** Favourable climate and soil, and availability of irrigation water are motivating growers to produce vegetables twice and three times in a year. These areas have rich water potential and immense cultivable land for irrigated horticulture. Converting available water resources in their surroundings to food production in the dry season has now become the tradition of small scale farmers. This expansion of irrigation has led to shifting subsistence production system towards targeting to maximize return per unit area, which further encouraged farmers to emphasize on high value vegetables such as onions.

In addition to untapped ground water potential, small rivers such as Erza and Shinta and big rivers such as Rib and Gumara are being used as sources of irrigation water around Fogera. Big dams for irrigation are also being constructed on these big rivers. The expansion of irrigation has further encouraged farmers to emphasize on high value vegetable and fruit crops. This shift to intensive production using irrigation is contributing towards tackling recurring drought and avoiding food dependency on rainfall alone.

It has to be stressed that Fogera and Dembia plains which were flooded and stayed unproductive during the rainy period are now changed to most productive areas for the cultivation of rice. Following rice harvesting from October through November, even those areas are being used for the production of vegetables using irrigation from the surrounding rivers. This production of crops twice in a year, mostly vegetables using irrigation is supporting to change the livelihood of many farmers, enabling them to afford sending their children to school and change their houses from grass thatched to roofs of corrugated iron. Many farmers have further developed capital to construct houses in the nearby towns and entered into other profitable businesses too including owning semi trucks and mini buses for public transportation.

Although horticultural crops are playing significant role in changing the livelihood of the farmers and towards economic growth of the region as well as the nation, access to improved and sustainable technologies suitable to the local condition is limited. Parallel to the expansion in the production system, farmers are facing several challenges of production and marketing. Onions are commonly produced in the off season using irrigation in Fogera district and around its vicinities. This results in seasonality of supply of high volume of produce to the market, leading into fall in price of onion bulbs.

Build up of disease and insect pest and dwindling soil fertility are also other challenges of repeated practices of monoculture. In the tropics where yields are often low, food crops result in less reliable returns (Ogunfowora and Norman, 1973; Ruthenberg, 1971). Small farmers, however, need to be certain that their investments of labour and capital are protected. According to Andrews and Kassam (1976), compared to mono cropping, multiple cropping has resulted in a greater dependability of return particularly with crops, which produce low yields. The intervention from research is therefore essential to further boosting production and productivity, targeting to sustaining the production system and raising income of farmers through the use of improved and ecologically friendly horticultural technologies. Intercropping different crops in a plot gives the opportunity to increase return and avoid risks of production and marketing. According to Matusso et al (2012) some of the principal reasons for smallholder farmers to intercrop their farms/crops include flexibility, profit maximization, risk minimization, soil conservation and soil fertility improvement. Intercropping is essential to reduce cost of production and increase profitability while at the same time sustain land resource base. Nyambo, et al (1982) showed that intercropping is the dominant peasant farming system in the tropics, and in Tanzania it is a traditional cropping practice characterized by minimal utilization of inputs such as fertilizers and insecticides. Intercropping helps to avoid or minimize build up of disease and insect pests, and risk of production. According to Sulvai, et.al (2016) intercropping of lettuce by onion control the caterpillar *A. ipsolon*, a major insect pest of lettuce. This phenomenon was justified by a higher average number of lettuce plants non-attacked in intercropped field compared (lettuce + onion) to mono crop field (lettuce alone).

Intercrops have the potentials to give higher yield than sole crops, greater yield stability and efficient use of nutrients (Seran and Brintha, 2010). Furthermore, better weeds control and improvement of quality while intercropping cereals with leguminous crops is reported by Ijoyah (2012). Similarly, Ali and Mohammad (2012) indicated considerable increase in forage quantity and quality and lessening condition for protein supplement from maize-legume intercrop.

While the overall target is to increase return and avoid risks of production and marketing, and build up of diseases and insect pests, specific objective of this study on intercropping of onion with other crops was therefore to identify appropriate companion crops to be intercropped with onion production in the off season using irrigation. It is also tried to pinpoint more productive and economical planting ratio (combination of planting rows or seeding rates) of the crops in the intercrop.

2. MATERIAL AND METHODS

2.1. Treatment and Experimental Design

The experiment was conducted in two off (dry) seasons using irrigation from December 2016 until April 2018. Treatments included sole onion, and onion intercropped with rape seed (locally used as leafy vegetable after cooking), kale, fenugreek, lentil, linseed, black cumin and dill. These were laid in a split plot arrangement in RCBD with three replications. Main plots were different companion

crops intercropped with onions while ratios of intercropping 1:1 (single row onion) and 2:1 (double rows onion) rows of onion and second crop, respectively, were arranged in sub plots.

Row intercropping - growing two crops at the same time with both crops planted in rows is practiced in these trials. Whereas two rows of onion alternating with a single row of the second crop was considered in double rows onion planting, single row onion planting comprised alternating one to one rows of onion and companion crop. Planting arrangements of the intercropping were 1 row onion to 1 row second crop (1:1) and 2 rows onion to 1 row the second crop (2:1). In single row onion planting (1:1 ratio), nine rows of each (1/2 + 1/2 seeding rate) onion and second crop were planted in a single plot while in double row onion planting 12 rows of onion and 6 rows (2/3 + 1/3 seeding rate) of the second crop were used.

Sizes of main plot and subplot were 5.4m x 3m and 5.4m x 1.5m, respectively. Gangways of 0.5m between plots and 1m between replications were employed. Planting was made on both sides of ridges (double row planting) with 20cm and 40cm width of ridge and furrow, respectively. Spacing between plants was 7cm for onion and drilling at 2-3 cm distance with the recommended seed rate was used for second crops. Intercrops (second crops) were sown two weeks after onion transplanting when onion seedling establishment is promising.

The main crop in the intercrop was onion (*Allium cepa* L.) variety Bombay Red while the second mixture of the intercrop include

- Lentil (*Lens culinaris* L.) is an annual crop, classified as a grain legume or pulse.
- Fenugreek (*Trigonella foenum-graecum* L.) is a legume pulse used as a spice and its leaves used as a herb, and also as an admixture in condiments and to flavour food.
- Linseed or flaxseed (*Linum usitatissimum L.)* is grown for oil, fiber, and food.
- Black cumin (*Nigella sativa* L.) is an annual medicinal plant.
- Dill (*Anethum graveolens L.*) is an annual herb its leaves and seeds are used as a spice for flavouring food.
- Rapeseed (*Brassica napus*) is a bright-yellow flowering member of the family Brassicaceae (mustard or cabbage family), cultivated mainly for its oil-rich seed. It is locally used as a leafy vegetable eaten after cooking and flavouring with spices. Fresh leaf yield similar to kale is considered in this study
- Kale or leaf cabbage are certain cultivars of cabbage (*Brassica oleracea*) grown for their edible leaves.

2.2. Description of the Study Area

The experiment was carried out on farmers' field at Wortea zuria (2016/17) and Quar Michael (2017/18) kebeles of Fogera district. These kebeles are located in the nearby of Fogera Agricultural Research Center. The Center is found in Woreta town of Fogera district of South Gondar Administrative zone in Amhara Region, Ethiopia. This area lies at 11° 58′ N latitude and 37° 41′ E longitude. It has an altitude of 1819 m above sea level and receives average annual rainfall of 1230 mm. Mean minimum and maximum temperature of the area is 12 and 28^{0}C, respectively. Soil of the site is red clay (vertisol) with a pH of 5.48.

2.3. Seedling Raising and Main Field Management

Seeds of onion variety Bombay red were sown eight weeks ahead of the transplanting date in the main field. Seedlings were raised in the nursery bed of the research center on 5m x 1m thoroughly prepared three adjacent beds, 5 cm raised from the surface. Seeds were drilled on rows with ten cm inter-row spacing and it was covered lightly with fine soil and mulched with eucalyptus leaves until emergence. Grass or straw mulching is not advised because it aggravates seedling damage by termites around the study area. Weeding was accomplished as deemed necessary. Water was regularly applied to seedling beds (seeds till emergence and thereafter seedlings) using watering can. Seedlings were thinned at first true leaf stage to allow sufficient spacing of 2-3cm within seedlings.

Seeds for the first experiment were sown in a nursery on the 10th October 2016 and transplanting in the field was made on 20th December 2016 where as in the second year seeds were sown in a nursery on the 6th October 2017 and transplanting in the field was made on the 13th December 2017.

Experimental field was thoroughly plowed and leveled, and ridges were then prepared on sides of which transplanting was done. Inorganic fertilizers in the form of Urea (46:0:0) (100kg/ha) and Nitrate phosphate sulfur (NPS) (19:38:7) (242kg/ha) were applied. NPS was applied at transplanting while urea is applied in two splits, the first at seedling establishment (1-2 weeks after transplanting) and the second one and half months after transplanting. Standard field management practices such as weeding and cultivation were performed uniformly during the growing seasons. These trials in off seasons of 2016/17 and 2017/18 were irrigated trials where furrow irrigation was the only practice employed once in a week starting at transplanting until two to three weeks before harvest.

3. DATA COLLECTION

Data was collected on seedling establishment, plant height at physiological maturity and maturity date. Harvested bulbs were cured for a week before neck cutting (foliage removal). Bulbs were then categorized into marketable and non marketable bulbs based on size, visible damages and rot.

Data was subjected to analysis of variance using SAS software version 9.2 and least significance difference (LSD) was used to compare treatment means when there was statistically significant difference ($P<0.05$).

4. RESULT AND DISCUSSION

Onion harvesting for the first trial was made on the 4th April 2017 where as the second trial was harvested on 12th April 2018. Early harvests of intercrops were obtained from rapeseed and kale. Furthermore, unlike the rest companion crops whose marketable yield is grain, yields from rapeseed and kale are fresh leaves which are liable to perish unless immediate market is arranged. Lentil and fenugreek were medium maturing intercrops which were harvested even earlier than the main onion crop (Table 3). Black cumin, linseed and dill were late maturing companion crops which were harvested after onion harvesting elapsed.

Apparently, the highest onion bulb yield was obtained from onion sole cropping mainly because of the use of full seed rate. Experience with intercropping in Africa has shown that the yield of one or all of the crops in the intercrop is lower than the yield of their respective pure stands (Nyambo, et al,1982) but the combined yield from the intercrop is higher than the yield of any of the crops as a pure stand. Among from intercrops, the highest onion bulb yield was, however obtained from intercropping with black cumin followed by kale, lentil and dill (Table 3). The lowest onion bulb yield was from intercropping with linseed followed by fenugreek and rape seed. From flowering onwards, linseed exhibited very much flourishing growth to the extent of over shading onion plants. This together with lateness in maturity could have exerted adverse competition with the main crop, eventually bringing about low onion bulb yield.

According to Taha and El-Mahdy (2014) the main goal of intercropping is to produce a greater yield on a given piece of land by making better use of growth resources that would otherwise not be utilized by a sole crop. They further indicate that land equivalent ratio (LER) is used as measure for land use efficiency of intercropped plants. It can be defined as the relative land area under sole crops that is required to produce the yields achieved in intercropping (Willey, 1979). Land equivalent ratio (LER) is calculated as $LER = \sum(YIi / YSi)$ Where YIi = yield of cropi in intercropping, YSi = yield of cropi in sole crop, n = total number of crops in association.

LERs above 1.0 show an advantage to intercropping while values below 1.0 show a disadvantage to intercropping. According to Sullivan (2003) an LER value of 1.25 indicates that the yield produced in the total intercrop would have required 25% more land if planted in pure stands.

In the dry season of 2016/17, the lowest LER was obtained from onion intercropping with fenugreek, linseed and lentil (Table 1). LERs for intercropping with fenugreek, linseed and lentil are lower than one indicating that intercropping onion with these crops were not advantageous than sole cropping. On the other hand, intercropping onion with dill, rape seed, kale and black cumin resulted in good LER revealing that these crops are suitable companions for dry season onion production. Alternating double onion rows with single second crop (2:1) gave higher LER than 1:1(onion and second crop) planting ratio but the difference between the two is insignificant in 2016/17.

Table1. *LER from onion intercropping in the dry season*

Crops	2016/17	2017/18
Lentil	0.98^{bcd}	1.40^{a}
Rape seed	1.49^{a}	1.37^{a}
Fenugreek	0.85^{d}	0.81^{c}
Linseed	0.91^{cd}	1.11^{b}
Kale	1.22^{b}	1.34^{a}
Dill	1.62^{a}	1.06^{b}
Black cumin	1.14^{bc}	1.07^{b}
Sole onion	1.00^{bcd}	1.00^{b}
CV	18.28	12.08
LSD	0.248	0.163
Planting ratio		
Single	1.1	1.21^{a}
Double	1.2	1.07^{b}
LSD	0.124	0.081

Means in a column followed by the same letter within a treatment group are not significantly different at P<0.05

In 2017/18 dry season, an unacceptable LER is obtained from onion intercropping with fenugreek indicating again its non suitability for intercropping with onion (Table 1). The rest second crops had LER value greater than one, the highest being from onion intercropping with lentil. For several reasons, it is advocated to intercrop leguminous with non leguminous crops. Amanullah, et al (2016) stressed that a popular combination of intercropping is cereal and legumes. In the dry season of 2017/18, inter cropping onion and second crops in 1:1 ratio had better LER than planting in 2:1 ratio.

Overall mean result from two season trials revealed that the highest land equivalent ratio (LER) was recorded from onion intercropping with rape seed followed by dill, kale, lentil, black cumin and linseed (Table 2). Intercropping with fenugreek had the lowest LER reflecting that onion intercropping with fenugreek is non advantageous than sole onion and sole fenugreek production. It was further demonstrated from the two years trial that fenugreek is not a suitable companion crop for intercropping with onion in the dry season. Wilting and death of fenugreek seedlings/plants observed in 2016/17 and powdery mildew attack on fenugreek in 2017/18 could presumably be attributable to poor performance of intercropping fenugreek and onion ultimately resulting in low LER.

The maximum LER of 1.43 from intercropping of onion with rapeseed explained that onion combined with rapeseed would save 0.43 hectare of land without any reduction in combined yield and these two crops are the best companions for offseason irrigated production practices (Table 2).

Table2. *Combined LER from results of two dry seasons in 2016/17 and 2017/18*

Crops	LER	Planting ratio	LER
Lentil	1.19^{cd}	Single	1.16
Rape seed	1.43^{a}	Double	1.14
Fenugreek	0.83^{f}	LSD	0.072
Linseed	1.01^{e}		
Kale	1.28^{bc}	Year	LER
Dill	1.34^{ab}	2016/17	1.15
Black cumin	1.11^{de}	2017/18	1.14
Sole onion	1.00^{e}	LSD	0.072
CV	15.35		
LSD	0.144		

Means in a column followed by different letter within a treatment group are significantly different at P<0.05

Intercropping onion with fenugreek is found inefficient as compared to sole cropping because LER is 0.83 (Table 2). However, LER of the rest crop combinations ranged from 1.01 to 1.43 indicating 1-43% yield advantage by intercropping. Similarly, Islam et al (2015) indicated LER of different crop combination ranged from 1.54 to 2.29 indicating 54-129% yield advantage by intercropping.

Overall average of two years result showed that the difference in LER between intercropping onion in single row (1:1 ratio or 1/2 + 1/2 seeding rate) and double row (2:1 ratio or 2/3 + 1/3 seeding rate) planting practices with the companion second crop is insignificant (Table 2). Determining the appropriate seed rate for the mixture of the intercrops is very critical to avoid intense overcrowding or below optimal population density. According to Sartajkhan et al (2014) LER increased with the increase in seed rates of Brassica in mixed cropping system but decreased with the increase in seed rates of Brassica in the intercropping system. They further showed that higher LER was calculated in 100:50 wheat-Brassica combinations in the intercropping system followed by 100:70 combinations in the mixed cropping system.

Table3. *Harvesting date and total marketable yield (qt/ha) of intercropping trial in 2017/18 dry season*

Crops	Yield of Onion	% non mark-etable yield	Yield of second crop	Harvesting date
Lentil	194.34^{c}	7.34	12.51	2nd April 2018
Rape seed	168.24^{cd}	12.23	135.39	14 Feb - 19 March 2018
Fenugreek	161.21^{cd}	10.84	4.88	10 April 2018
Linseed	158.04^{d}	13.88	7.30	19 April 2018
Kale	233.35^{b}	6.30	69.52	27 Feb – 19 March 2018
Dill	181.22^{cd}	12.44	8.29	25 April 2018
Black cumin	234.46^{b}	7.39	4.20	23 April 2018
Sole onion	361.24^{a}	7.54		12 April 2018
CV	13.91	9.50		
LSD	34.42			
Planting ratio				
Single	187.17^{b}			
Double	235.85^{a}			
LSD	17.21			

Means in a column followed by the same letter within a treatment group are not significantly different at P<0.05

Considering the influence on soil fertility, legumes are more advised for intercropping with onion if the competition with the main crop is not adverse bringing about LER value below one. In this regard lentil is a suitable crop for intercropping which had 1.40 LER resulting in an increase of 40% land use efficiency over sole cropping in 2017/18 dry season. Similarly, from corn-legume inter-cropping, a land equivalent ratio (LER) between 1.48 and l.66 is reported by Polthanee and Tre1o-ges (2003). These LER indicate that 48 to 66% more land would have been used in single cropping to produce the same quantities of corn and legumes as in the inter-cropping systems further reflecting 48% to 66% increment in land use efficiency from corn-legume intercropping depending on legume species. According to Rana and Pal (1999), low input and high risk environment of the smallholder farmer benefits enormously from intercropping. For early harvest in small scale production of smallholder farmer where marketing is not a problem, preference could be given to intercropping onion with rape seed and kale, whereas for large scale production, preference could be given to intercropping onion with grain crops such as lentil and black cumin. In general, types and choices of best companion crops grown are normally governed by physical, economic, and social factors. In addition to profitability interms of productivity and quality per unit area, fitness into environmentally acceptable and sustainable vegetable-producing practices, scale of production, demand from market and need for early income are considered while intercropping different crops.

5. Conclusion and Recommendation

Early harvests of intercrops (second crop) were made from rape seed and kale. Lentil and fenugreek were medium maturing intercrops which were harvested even earlier than the main onion crop. Crops maturing before its companion crops could help to lessen the competition between the two crops-creating favourable companionship with good LER value. Furthermore, unlike the rest companion crops, yield from rapeseed and kale is fresh leaves with poor storability requiring immediate marketing. Black cumin, linseed and dill were late maturing companion crops which were harvested after onion harvesting is over. Very much flourishing growth was also observed from linseed. This along with lateness in maturity of linseed could be attributable to fierce competition with onion

leading to low LER. It would also be meaningful to consider different planting time for the intercrops if either of the mixture in the intercrop is aggressive in competition mainly because of flourishing growth or other reasons such as maturity period. Seeding rate of each crop in the mixture of the intercrops is also very critical and it is usually adjusted below its full rate.

Except for intercropping onion with fenugreek which was found inefficient than sole cropping, intercropping onion with other crops (lentil, black cumin, dill, linseed, rapeseed and kale) considered in this study is advantageous than sole cropping. The type and choice among several appropriate companion crops for intercropping with onion production in the dry season depends on productivity and profitability, market demand, sustainability and scale of production.

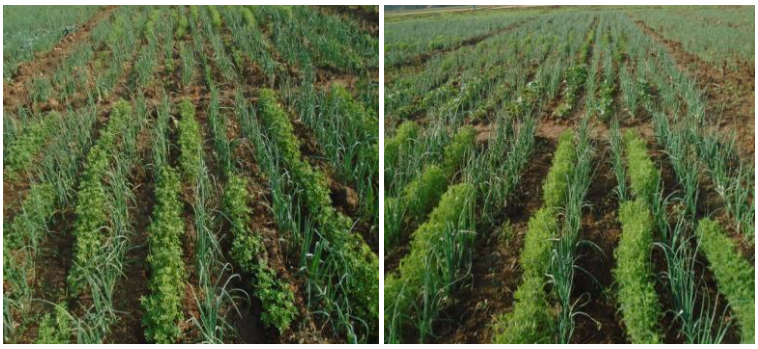

Fig1. *Picture showing rows of intercrops at early vegetative growth*

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