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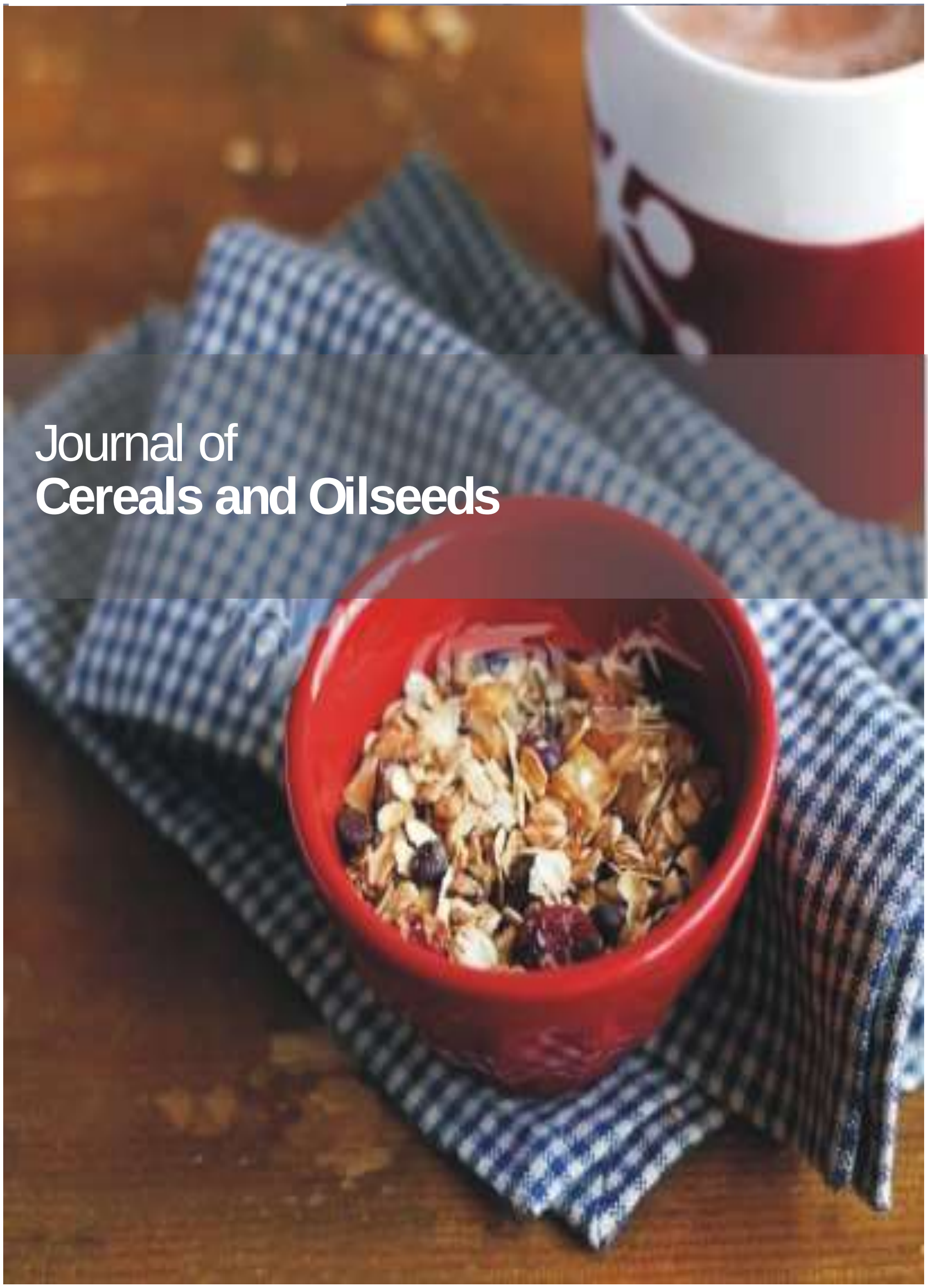

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Full Length Research Paper

Effect of *Alternaria* sp on seed germination in rapeseed, and its control with seed treatment

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The role of *Alternaria* sp on seed vigor of rapeseed, *Brassica napus,* was investigated. Seed samples were collected from rapeseed growing regions of Sindh province. The samples were processed for fungal recovery using blotter paper and agar plate methods. Both methods produced a number of parasitic and saprophytic fungi. Among the recovered fungi, *Alternaria* sp was predominant with 16% average infection. Similarly, effect of seed treatment with Topsin M. was examined in this experiment. It improved seed health significantly over inoculated seeds. The treated seeds showed greater germination (16.15%) with 83.69% more healthy seedling in comparison with inoculated seeds. Root and shoot systems were significantly improved in seedlings from treated seed compared to those from inoculated seeds. The results of this study suggest grading seed samples to reduce seed impurities and seed treatment (particularly with Topsin M) to eliminate seed borne pathogen, especially Alternaria from rapeseed to enhance production by the growers.

Key words: Seed health, seed borne fungi, *Alternaria*, seed treatment.

INTRODUCTION

Seed health is a key factor in sustainable crop production. Disease free plants ensure a healthy crop stand in the field. This provides better outputs at farm level. However, seed borne pathogens are known to affect seed health and its vigor. A number of crop diseases are disseminated to distinct areas through infected seeds (Kandhare, 2014). As a result, new diseases are easily established in those environments. Seed contamination with such pathogens occurs in many ways like direct infection on the field and improper storage conditions. High relative humidity, suitable temperature and higher moisture content enhance pests and diseases establishment in seeds. Infestation by these fungi has been observed in all parts of the seeds as it harms seed tissues externally or internally causing seed rot, necrosis and seedling diseases (Anwar et al., 1994; Al Kassim 1996; Rai et al., 2015).

Pre- and post-emergence seedling diseases contribute significantly to poor crop stands. Majority of plant pathogens that attack rapeseed are seed borne in nature.

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Particularly, *Alternaria brassicola, Alternaria alternate, Curvularia lunata* and *Fusarium* spp. are of great concern. *A. brassicicola* is the most common pathogen of most crops belonging to the same group as rapeseed along with *A. alternata* (Gupta and Chaudhary, 1994). Black spot in rapeseed due to *A. brassicicola* is a seed borne disease. *Alternaria* is known to produce a number of toxins which help it to overcome the host resistance. These toxins cause tissue necrosis with cell-wall degrading enzymes (Ahmad and Sinha, 2002; Cho et al., 2016; Zaheer et al., 2015).

Therefore, early defoliation, flower-bud abortion, and premature ripening due to severe infection of these diseases results in substantial yield losses (Seidle et al., 1995; Kumar et al., 2014). Under such circumstances, 20 to 30% losses in rapeseed yields have been observed in Canada (Mc Donald, 1959; KL et al., 1990). Apart from this effect, a number of seed-borne fungi including *Aspergillus flavus*, *A. ochraceus, Rhizopus, Mucor* and *Fusarium* spp. produce mycotoxins.

Consequently, these toxins not only reduce germination but also induce biochemical changes in seeds (Kandhare, 2015; Farid et al., 2017a; b). In oilseed crops, the presence of these fungi in seed deteriorates oil and sugar contents, and their quality. Oil seed crops are very important for edible oil production worldwide. But these have not gained much importance in Pakistan. Currently, due to increased demand of good quality edible oils, special focus is being given to exploit the potential of local and exotic rapeseed germplasm. Significant achievements at national level have been made in canola types with better oil content than the indigenous material. This has increased the demand for good quality and disease-free seed of these genotypes at farm level. The present investigation was carried out on the association of *Alternaria,* and other seed mycoflora with rapeseed.

MATERIALS AND METHODS

Collection of seed samples

Seed samples of rapeseed were collected from grain markets, and farmers' lots from rapeseed growing pockets of Sindh. The samples inspected were processed for the association of seed-borne fungi followed (ISTA, 2005) by visual/dry inspection of seeds, standard blotter paper and agar plate methods and seedling assay.

Visual/dry inspection of rapeseed seeds

1 kg seed of each sample was examined visually for the presence of impurities, broken seeds or any fruiting structure. Contaminated seeds were observed under stereomicroscope for the confirmation of these impurities.

Standard blotter paper method

Seeds of each sample were placed aseptically on three layers of water soaked blotter paper. The experiment was conducted under completely randomized design (CRD) with five replications. Five seeds were placed in each Petri plate (9 cm), and three petri plate of each sample per replication were used. The plates were incubated at 25±2°C for 7 days under fluorescent light (ISTA, 1993). After incubation, seeds were examined under stereoscopic microscope. The initial growth of each fungus was purified on potato dextrose agar (PDA) medium. Percentage infection for each fungus was calculated by counting infected seed out of the total plated seeds.

Agar plate method

Potato dextrose agar medium was used for fungal recovery from rapeseed seeds. Media and glassware were sterilized at 121°C, and 15 lbs psi for 15 min. About 15 ml of sterilized PDA medium was poured in each Petri dish (9 cm) under aseptic conditions. 5 seeds of each sample were placed directly in each Petri dish containing nutrient media under aseptic conditions. The Petri plates were incubated at 25±2°C for 7 days. The experiment was conducted under CRD with five replications. Each fungus was identified on the basis of spore/ conidia formation under a compound microscope according to Booth (1971), Ellis (1971), Barnett and Hunter (2003), Subramanian (1971), Larone (2002) and Schell (2003) in addition to the use of various keys and pictograms.

Seed inoculation

Inoculum of *Alternaria* was prepared for pathogenicity test. Seeds of the test cultivars were dipped in the conidial suspension (10^6 conidia ml^{-1}) of each fungus. These seeds were sown in earthen pots containing sterilized soil. One hundred seeds of each sample were sown in earthen pots with three replications using completely randomized design. Untreated seeds sown in earthen pots served as control. Isolations were also made from the seeds that failed to germinate, and infected seedlings to re-isolate the fungus.

Effect of fungicides dressing on seed-borne mycoflora of rapeseed seeds

Composite seed samples of each rapeseed sample were treated with thiophenate methyl (active ingredient Topsin-M) at 2.5g/ Kg seed. The treated seeds were sown in earthen pots containing sterilized soil under greenhouse condition. The seeds without fungicides treatment served as control. Germination in treated and non treated seeds was recorded after 7 days. Similarly, the germination % rotted seeds, abnormal seedlings and root shoot length were calculated.

RESULTS

Association of various seed borne fungi with rapeseed seeds

The presence of seed impurities such as fruiting bodies, dead and dry seeds were examined visually using magnifying glasses for estimation. All the samples showed the presence of these impurities. However, the overall proportion of seed debris was significantly higher than the broken seeds. Straw, dust particles, and seeds of other crops were the main debris in all samples.

These were less in sample numbers 17 and 18 while

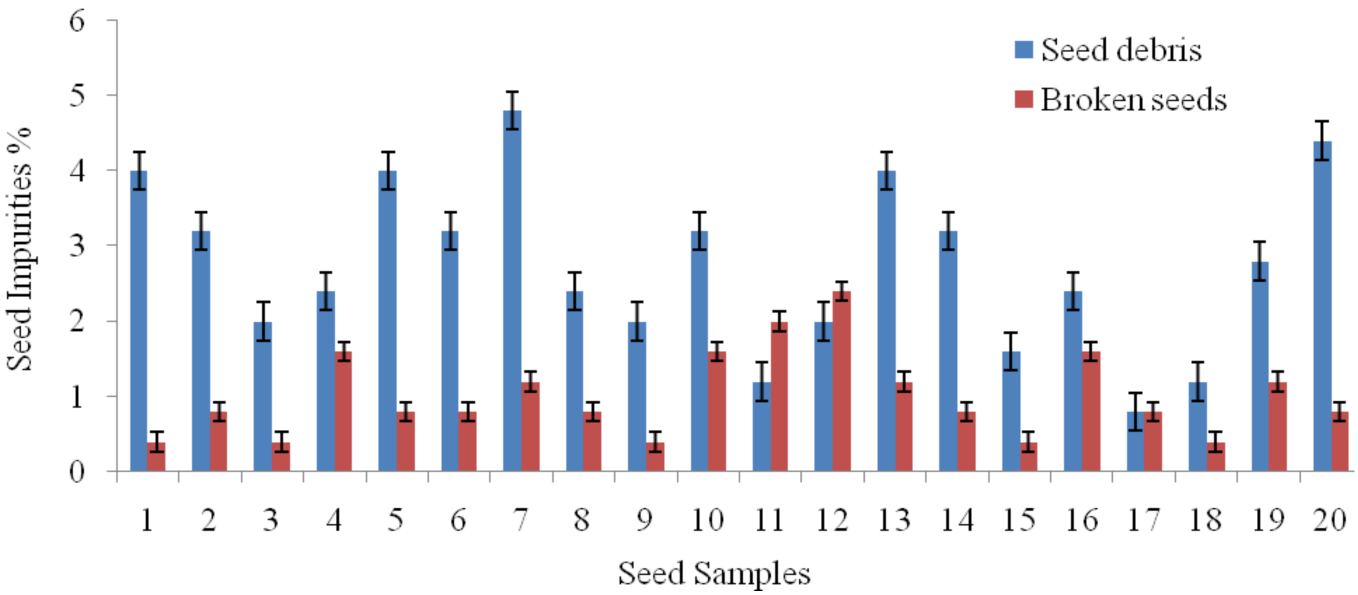

Figure 1. Association of impurities in seed samples.

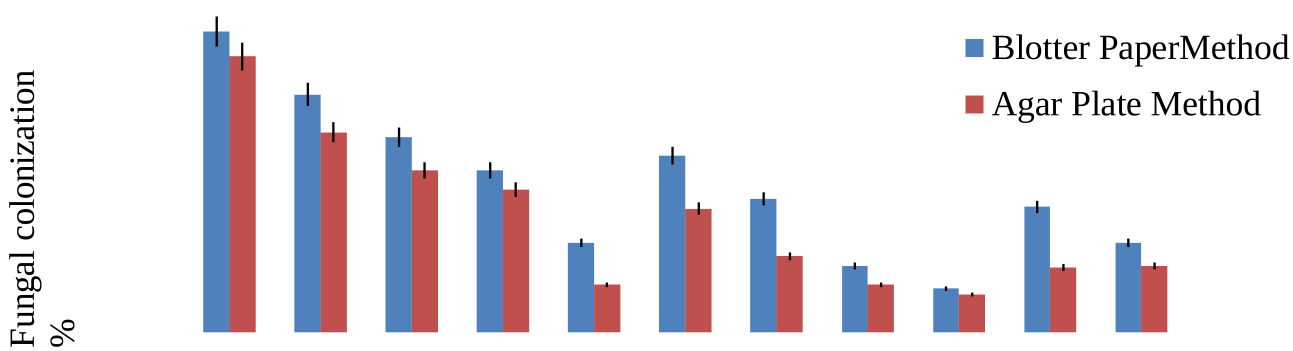

Figure 2. Fungal colonization with seed samples of Rapeseed

their percentage was higher in samples 1, 7, 13 and 20. Broken seeds and mummies were observed in all samples. These may result during postharvest or some other physical damages (Bux et al., 2013). These are not only the cause of disease spread but also provide a good shelter for overwintering and survival of pathogens (Figure 1).

Blotter paper and agar plate methods were used for the recovery of *Alternaria* from seed samples. The results revealed that its colonization was significantly higher in blotter paper (Figure 2). In order to find and examine the maximum fungal population, seed blotter paper method was seen to be very effective (Elwakil and Ghoneem, 1999; Walcott, 2003). This provided excellent conditions for mycelial growth and sporulation of several fungi (Neergaard, 1979). Morphological characteristics were identified according to Larone (2002) and Schell (2003). Apart from *Alternaria*, a number of other fungi were also observed. The present results are also in conformity with Saleh et al. (2003), who have reported the prevalence of various seed borne fungi in rapeseed. *Alternaria* sp is responsible for leaf spot disease in oil seeds and also for loss of seed viability (Malaker et al., 2008).

Effect of culture filtrate of *Alternaria* and fungicide dressing on seed health of rapeseed

The results of this study revealed significant differences in seed germination, number of abnormal seedling and root shoot length in inoculated and treated seeds. The seedlings of the treated seeds (Table 2) were healthy

Table 1. Effect of culture filtrate of *Alternaria* on seed health of rapeseed.

Seed sample	% Germination	Rotten seeds	Abnormal seedlings	Root length(cm)	Shoot length(cm)
1	77.00^{BCDEF}	6.6667^{CDE}	8.67^{EF}	4.33^{CD}	4.33^{ABCDEF}
2	77.67^{BCDE}	7.3333^{CDE}	12.00^{BC}	4.00^{CDE}	4.33^{ABCDEF}
3	74.67^{EFGHI}	8.00^{BCDE}	10.67^{CDE}	2.67^{FGH}	3.00^{EF}
4	78.00^{ABCD}	6.67^{CDE}	12.67^{ABC}	3.33^{DEFG}	3.67^{CDEF}
5	73.67^{GHI}	8.33^{BCDE}	12.00^{BC}	2.33^{GH}	3.33^{DEF}
6	79.33^{AB}	5.00^{E}	14.33^{A}	3.67^{DEF}	4.67^{ABCDEF}
7	75.33^{DEFGHI}	7.00^{CDE}	14.00^{AB}	3.33^{DEFG}	3.00^{EF}
8	76.67^{BCDEFG}	9.67^{ABC}	12.00^{BC}	2.00^{H}	2.67^{F}
9	74.67^{EFGHI}	8.67^{ABCD}	10.67^{CDE}	6.00^{B}	5.00^{ABCDE}
10	79.33^{AB}	9.67^{ABC}	9.67^{DE}	3.67^{DEF}	2.67^{F}
11	79.00^{ABC}	11.33^{AB}	7.00^{F}	3.00^{EFGH}	3.33^{DEF}
12	72.67^{I}	12.00^{A}	12.67^{ABC}	7.33^{A}	5.33^{ABCD}
13	75.67^{DEFGHI}	8.67^{ABCD}	11.00^{CD}	6.00^{B}	4.0^{BCDEF}
14	76.00^{CDEFGH}	7.67^{CDE}	14.00^{AB}	3.67^{DEF}	4.33^{ABCDEF}
15	77.00^{BCDEF}	7.00^{CDE}	11.00^{CD}	6.00^{B}	6.33^{A}
16	81.0^{A}	5.67^{DE}	9.00^{DEF}	2.67^{FGH}	3.00^{EF}
17	76.67^{BCDEFG}	8.33^{BCDE}	11.00^{CD}	5.00^{BC}	6.00^{AB}
18	75.33^{DEFGHI}	11.33^{AB}	12.67^{ABC}	7.33^{A}	5.67^{ABC}
19	73.00^{HI}	12.00^{A}	13.33^{AB}	5.00^{BC}	5.33^{ABCD}
20	74.33^{FGHI}	7.00^{CDE}	12.33^{ABC}	4.00^{CDE}	4.00^{BCDEF}
S^{E}	1.5951	1.7826	1.1304	0.6498	1.0853
LSD	3.2239	3.6028	2.2846	1.3133	2.1934

with proper root and shoot. No abnormal symptoms were observed. However, in inoculated seeds (Table 1), less seed germination and more abnormal seedlings with reduced root and shoot system were observed. Seed mycoflora is reported to reduce seed germination thus causing pre- and post- emergence seedling death. Shrestha et al. (2000) in a pathogenicity study observed symptoms of *Alternaria* in rapeseed seedlings. Similarly, the infection deteriorates seed health and reduces germination (Ismail et al., 2004; Anwar et al., 1994; Elwakil and Ghoneem 1999). Nowadays, chemical seed treatment is very common worldwide due to its wide spectrum ability to control plant diseases (Nameth, 1998). In our farming system, this could not get much importance, there is need to educate farmers about seed treatment.

DISCUSSION

The present work revealed the occurrence of various impurities in all collected samples. Among the twenty rapeseed samples, only a few showed fewer impurities (Figure 1). Presence of such impurities affects seed health and marketing. Among the methods of fungal detection from rapeseed blotter paper method, agar plate was found to be very effective. *Alternaria* was the most predominant fungus with an average infection of 16% in all samples among the isolated fungi.

The location of *Alternaria* in seed is very important. It mostly resides in seed coat and sporulates in the hilum Region (Shrestha et al., 2003; Walcott 2003). Seed infection transmits *Alternaria* to seedlings. Plant pathogenic *Alternaria* sp produces host specific toxins, and use secondary metabolites in disease initiation, apart from toxins, certain lipase and cell wall-degrading enzymes contribute significantly in its pathogenesis (Chao, 2016; Rathod, 2012).

Seed borne fungi are responsible for mycotoxin production in seeds, and induce biochemical changes resulting in damaged seed contents (Swami and Alane, 2013). As a result, quality of oil contents in seed is affected (Wani et al., 2012).

The role of *Alternaria* in seed germination was also investigated in this study. Reduced seed germination was observed in all samples. The important symptom found were seed rot, lesion on seedling and reduced root shoot system. Successful re-isolations were made from infected seedlings and rotted seeds. These results are in conformity with Shrestha et al. (2005) who observed that lesions on cotyledonary and first true leaves were due to seed-borne inoculum. Adverse effects of mycotoxins which inhibited the growth of seedlings have been reported by Howlett (2006). Impact of fungicides treatment on fungal population was also investigated in this study.

Significant difference was noticed in seed germination

Table 2. Effect of fungicide dressing on seed health of Rapeseed.

Treated with Topsin.M (2.5g/kg seeds)					
Seed samples	**% germination**	**Rotted seeds**	**Abnormal seedlings**	**Root length (cm)**	**Shoot length(cm)**
1	94.33^{A}	4.33^{E}	1.00^{D}	7.33^{AB}	12.0^{ABCD}
2	91.00^{DEFG}	5.67^{CDE}	2.00^{C}	7.00^{AB}	12.0^{ABCD}
3	90.33^{DEFGH}	8.33^{AB}	2.00^{C}	7.67^{AB}	11.33^{ABCDE}
4	89.67^{FGH}	9.33^{A}	1.00^{D}	7.33^{AB}	10.00^{DE}
5	90.67^{DEFGH}	7.33^{ABCD}	2.00^{C}	7.33^{AB}	9.67^{E}
6	91.67^{BCDEF}	7.67^{ABCD}	0.67^{E}	7.67^{AB}	11.00^{BCDE}
7	91.67^{BCDEF}	8.00^{ABC}	1.00^{D}	7.33^{AB}	9.67^{E}
8	92.00^{BCDE}	6.00^{BCDE}	2.00^{C}	7.67^{AB}	11.67^{ABCDE}
9	92.33^{ABCD}	6.33^{BCDE}	3.00^{B}	7.67^{AB}	12.33^{ABC}
10	93.333^{ABC}	6.00^{BCDE}	1.00^{D}	7.33^{AB}	13.00^{AB}
11	88.67^{H}	7.00^{ABCD}	3.00^{B}	6.67^{B}	11.33^{ABCDE}
12	89.00^{GH}	7.67^{ABCD}	3.00^{B}	8.00^{AB}	12.33^{ABC}
13	90.00^{EFGH}	5.33^{DE}	4.00^{A}	7.33^{AB}	10.67^{CDE}
14	92.00^{BCDE}	5.67^{CDE}	1.00^{D}	6.67^{B}	10.33^{CDE}
15	90.67^{DEFGH}	6.33^{BCDE}	3.00^{B}	7.67^{AB}	10.33^{CDE}
16	93.67^{AB}	6.33^{BCDE}	1.00^{D}	8.67^{A}	10.67^{CDE}
17	93.667^{AB}	6.33^{BCDE}	1.00^{D}	8.00^{AB}	10.67^{CDE}
18	93.333^{ABC}	7.00^{ABCD}	2.00^{C}	8.00^{AB}	12.00^{ABCD}
19	91.33^{CDEF}	7.00^{ABCD}	2.00^{C}	7.33^{AB}	12.00^{ABCD}
20	89.67^{FGH}	7.67^{ABCD}	2.00^{C}	7.00^{AB}	13.33^{A}
SE	1.1255	1.2472	0.1054	0.8756	1.0853
LSD	2.2746	2.5207	0.2130	1.7696	2.1934

Table 3. Comparison of seed treatment and seed inoculation**.**

Seed health parameter	**Treated**	**Inoculated**	**% improvement**
Germination %	91.45	76.35	16.15
Rotted seed	6.89	8.4	17.97
Abnormal seedlings	1.88	11.53	83.69
Root length	7.48	4.26	43.04
Shoot length	11.32	4.19	62.98

and seedling health of treated and untreated seed (Table 3). The seeds treated with Topsin M showed maximum germination with healthy seedlings. These results are in accordance with Bhuiyan et al. (2013) and Sharma et al., (2015) who have observed better seed germination in fungicide treated seed. Sinha and Prasad (1981) reported less seed germination as a result of *Alternaria* infection*.* In order to reduce such infection, improving seed treatment is an effective method (Anjorin and Mohammad, 2014; Naher et al., 2016).

This does not only reduce seed borne infections but also protects the emerging seedlings from fungal infection (Kamal and Verma, 1987). As a result, pre- and post- emergence seedling mortality are reduced. According to Chilkuri and Giri (2014), seedling blight was due to seed borne fungi infection. The present work highlights the association between *Alternaria* and rapeseed. From the aforementioned, it can be concluded that blotter paper is an effective method in detecting seed borne infection such as *Alternaria*.

Seed borne fungi reduces seed germination (as is evident from the present results) therefore, seed treatment is recommended. It is also suggested that awareness must be created among farmers about seed treatment so that they can protect their crops from these pathogens. Foliar application of fungicides is an important component of disease management in plants. Therefore, judicious use of these fungicides especially, Topsin M, is recommended to overcome *Alternaria* diseases in rapeseed crop.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Ahmad MS, Sinha KK (2002). Influence of aflatoxin B 1 on seed germination, seedling growth, chlorophyll and carotenoid contents of mustard (*brassica juncea* L. var. pusa bold) seeds. Mycotoxin research 18(1):2-6.

Anjorin ST, Mohammad M (2014). Effect of seed borne fungi on germination and seedling vigor of water melon (*Citrllus lanatus* thum). African Journal of Plant Science 8(5):232-236.

Anwar SA, Rauf CA, Bhutta AR (1994). Seed-borne fungi of pea seed and their role in germination. Pakistan Journal of Phytopathology 6:135-139.

Barnett HL, Hunter BB (2003). Illustrated Genera of Imperfect Fungi, 218 p. The American Phytopathological Society Press, St. Paul, MN USA.

Bhuiyan MR, Rashid MM, Khan MA, Hoque M, Nessa B, Rafi MY, Latif MA (2013). Eco-friendly management of seed borne fungi for sustainable crop production. Life Science Journal 10(4):1640-1650.

Booth C (1971). The Genus *Fusarium*. Commonwealth Mycological Institute, Kew, Surrey, England.

Bux M, Khan MH, Ahmad N, Tofique M, Ismail M (2013). Field comparison of different rice (*Oryza sativa* L.) genotypes for their resistance against rice stem borers (Pyralidae: Lepidoptera). Pakistan journal of agriculture, agricultural engineering and veterinary sciences 29(2):137-145.

Chilkuri A, Giri GK, (2014). Detection and transmission of seed-borne mycoflora in Green gram and effect of different fungicides. International Journal of Advanced Research 5(5):1182-1186.

Ellis MB (1971). Dematiaceous hyphomycetes. Dematiaceous hyphomycetes.

Elwakil MA, Ghoneem KM (1999). Detection and location of seed-borne fungi of black cumin and their transmission in seedlings. Pakistan Journal of Biological Sciences 2(2):559-564.

Farid M, Ali S, Rizwan M, Ali Q, Abbas F, Bukhari SAH, Saeed R, Wu L (2017a). Citric acid assisted phytoextraction of chromium by sunflower; morpho-physiological and biochemical alterations in plants. Ecotoxicology and environmental safety 145-90-102.

Farid M, Ali S, Akram NA, Rizwan M, Abbas F, Bukhari SAH, Saeed R (2017b). Phyto-management of Cr-contaminated soils by sunflower hybrids: physiological and biochemical response and metal extractability under Cr stress. Environmental Science and Pollution Research 24(20):16845-16859. doi:10.1007/s11356-017-9247-3

Gupta DK, Basu Chaudhary KC (1994). Seed microflora of vegetable mustard. Indian Phytopathology 47(4):422-423.

Howlett BJ (2006). Secondary metabolite toxins and nutrition of plant pathogenic fungi. Current opinion in plant biology 9(4):371-375.

Ismail M, Haque MI, Riaz A (2004). Seed borne mycoflora of Safflower *Carthamus tinctorius* L and their impact on seed germination. Mycopath 2(1):51-54.

Muhammad I, Anwar SA, Azar I, Nazir A, Arain MA (2012). Seed-borne fungi associated with Cauliflower seeds and their role in seed germination. Pakistan Journal of Phytopathology 24(1):26-31.

International Seed Testing Association (ISTA) (1993). International rules for seed testing proceedings. Seed Science and Technology 21:1-28

International Seed Testing Association (ISTA) (2005). Seed health testing methods and the germination.In. ISTA ,pub. By ISTA, Bassersdorf, Switzerland.

Jalander V, Gachande BD (2012). Effect of fungal metabolites of some Rhizosphere soil fungi on seed germination and seedling growth of some pulses and cereals, Science research reporter 2(3):265-267

Kamal, Verma AK (1987). Seed-borne mycoflora of Arhar (T-21), effect of culture filtrates of some isolates on seed germination and fungicidal treatment. Indian journal of mycology and plant pathology 9(1):41-45.

Kandhare AS (2014). Seed-borne fungi and their effect on seed health of green gram. Bioscience Discovery 5(2):251-255.

KL C, Tewari JP, Awasthi RP (1990). A disease assessment key for Alternaria blackspot in rapeseed and mustard. Disease des plantes Survey'au Canada 70(1):19

Kandhare AS (2015). Seed borne fungi of pulses and their protease activity on black gram. International Journal of Recent Biotechnology 3:22-24.

Kumar D, Maurya N, Bhararti YK, Kumar A, Kumar K, Shrivastava K, Chand G, Kushwana C, Singh K, Mishra RK, Kumar A (2014). Alternaria blight of oilseed rapeseeds, A. comrepensive review. African Journal of Microbiology Research 8(30):2816-2829.

Larone DH (2002). Medically important fungi A guide to identification. 4th Ed. ASM Press, Washington, D.C. P 221.

Malaker PK, Mian IH, Bhuiyan KA, Akanda AM, Reza MMA (2008). Effect of storage containers and time on seed quality of wheat. Bangladesh Journal of Agricultural Research 33:469-477.

McDonald MC (1959). Gray leaf spot of rape in Manitoba. Canadian, Canadian Journal of Plant Science 39:409-418.

Naher L, Ali MA, Sheheli S (2016). Effect of seed treatment on seed borne fungi of rice. Progressive Agriculture 27:48-56.

Naikoo A, Mubashir W, Nazir AB, Waheed Z, Suliman M, Mahmood AT (2013). Effect of seed borne mycoflora on the quality of three varieties of *Arachis hypogea* L. International Journal of Agricultural Science and Research 3(1):35-42.

Nameth ST (1998). Priorities in seed pathology research. Scientia Agricola 55(SPE):94-97

Neergaard P (1979). Seed Pathology. Them MacMillan Press Ltd., London 1191:1-2.

Rai PK, Shadav M, Pankaj S, Garg G (2015). Seed-borne mycoflora associated with stored mustard (*Rapeseed juncea* L.) seed and their pathogenic potential. Vegetos 28(2):208.

Rathod S (2012). Seed borne *Alternaria* species: A review. Current Botany 3(2):21-23.

Saleh MA, Latif MA, Khan I, Rahman H, Uddin MK (2003). Prevalence of fungi in mustard seeds grown and stored at different locations of Dhaka region, Bangladesh and their control Sciences. 6(11):995-997.

Seidle E, Rude S, Petrie A (1995). The effect of *Alternaria* black spot of canola on seed quality and seed yield andstudies on disease control. Agriculture and Agri-Food Canada Saskatoon, Canada 41 p.

Sharma KK, Singh US, Sharma P, Kumar A, Sharma L (2015). Seed treatments for sustainable agriculture. A review. Journal of Applied and Natural Science 7(1):521-539.

Schell WA, (2003). Bipolaris, Exophiala, Scedosporium, Sporothrix, and other dematiaceous fungi. Manual of clinical microbiology pp. 1820-1847.

Shrestha SK, Mathur SB, Munk L (2000). Alternaria brassicae in seeds of rapeseed and mustard, its location in seeds, transmission from seeds to seedlings and control. Seed Science and Technology (Switzerland) 28(1):75-84.

Shrestha SK, Mathur SB, Munk L (2003). Survival of *Alternaria rapeseede* in seeds and crop debris of rapeseed and mustard in Nepal. Seed science and technology 31(1):103-109.

Shrestha SK, Munk L, Mathur SB (2005). Role of weather on *Alternaria* Leaf Blight disease and its effect on yield and yield components of mustard. Nepal Agriculture Research Journal 6:62-72.

Sinha MK, Prasad T (1981). Effect of fungal metabolites on seed germination, microbial association and seedling growth of Mung. Indian Phytopathology 34(4):515-517.

Wani M, Bakshi SH, Bhat NA, Zaman WU (2012). Effects of seed borne mycoflora on sugar, oil and fatty acid composition of three varieties of mustard (*Rapeseed compestris*) viz, Basanti, Kalasona, Kaveri Ak-47. International Journal of Pharma and Bio Sciences 3(4):421-428.

Walcott RR (2003). Detection of Seed-borne pathogens. HortTechnology 13(1):40-47.

Zaheer IE, Ali S, Rizwan M, Farid M, Shakoor MB, Gill RA, Najeeb U, Iqbal N, Ahmad R (2015). Citric acid assisted phytoremediation of copper by *Brassica napus* L. Ecotoxicology and environmental safety 120:310-317.

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Growth and yield response of two groundnut cultivars to row pattern in the forest-Savannah Transition Zone of Ghana

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Two field trials (2017 and 2018) were conducted at the research field of the University of Education, Winneba, Mampong Campus from May to August to determine the growth and yield response of groundnut to row pattern. The experimental design was a 2 x 4 factorial arranged in a randomized complete block design (RCBD) with three replications. The factors studied included: (A) Cultivar [(i) *Yenyawoso* and (ii) *Adepa*] and (B) Row pattern [(i) 50 cm × 10 cm, (ii) 60 cm × 10 cm single row, (iii) 50 cm × 20 cm × 20 cm (iv) 60 cm × 20 cm × 20 cm twin row]. The result revealed that Adepa produced taller plants, higher number of branches at 86 DAP, taller plants, 100 - seed weight and number of pods/ plant than Yenyawoso. The 50 cm × 20 cm × 20 cm twin row pattern produced higher number of branches, taller plants, number of plants harvested and pod yield than other row pattern. The 60 cm × 20 cm × 20 cm twin row pattern produced higher 100 - seed weight and higher number of pods/plant than 50 cm × 10 cm and 60 cm × 10 cm single row pattern. Interaction effect between variety x row pattern was significant with number of branches at 58 and 86 DAP in 2018 cropping season. In conclusion groundnut farmers are to grow Adepa cultivar of groundnut using 50 cm × 20 cm × 20 cm twin row pattern for high yield and vegetative biomass. For heavy seeds farmers should grow Adepa using 60 cm × 20 cm × 20 cm twin row pattern.

Key words: Groundnut, Adepa, Yenyawoso, single row pattern, twin row pattern.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the world most popular crops grown in tropical and sub-tropical regions. The crop belongs to the family Fabaceae. It originated from South American, but it is now widely

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cultivated throughout the tropical, sub-tropical and temperate countries, and in Africa, Asia, North and South America. Due to its high protein, oil, fatty acid, carbohydrates, vitamins and minerals content, the crop has high commercial and nutritional values. Groundnut seeds are a rich source of oil (35-56%), protein (25-30%), carbohydrate (9.5-19%) and minerals (Gulluoglu et al., 2016a); Gulluoglu et al., (2016c). In Ghana, the paste obtained after the oil has been extracted can be moulded into different shapes and fried as "krukli". The crop is intercropped with other cereal crops such as pearl millet, maize, sorghum and cassava. Its cake is used as feed and haulms provide quality fodder (Martey et al., 2015).

Groundnut production in Africa covers 31.3%l land area and 18.6% production. Ghana is one of the top six countries producing groundnut in Africa (FAO, 2008). Groundnut total production in Ghana range from 209,000 tons in 2000 to 530887 tons in 2010 and it is mostly produced by smallholder farmers (Angelucci and Bazzuchi, 2013). It is estimated that more than 70% of farmers in the three northern regions of Ghana grow groundnuts and together account for over 85% of the national output. Groundnut is an important legume crop grown and marketed by farmers in the study area. The crop provides substantial income which has helped to improve their livelihoods over the years. Most of the grains are transported to large market centres where they are sold and used for food and oil preparations. However, production has been on subsistence level with low crop yield. This is due to inappropriate use of agronomic factors such as row planting pattern. In addition farmers have been using local groundnut varieties for cultivation which usually give low yield. Single row planting pattern has been a traditional cultivation method used by groundnut farmers in the forest-savannah transitional agro-ecological zone of Ghana. For improved groundnut varieties it is important to accommodate the most appropriate row planting pattern and number of plants per unit area to obtain better yield (Gulluoglu et al., 2016b). Understanding the proper planting pattern is very important to increase crop yield (Knezevirc et al., 2003). A particular planting pattern for a specific leguminous crop may provide an optimum space to maximize vegetative parts which will receive higher solar energy and results in maximum yield. Adjusting row planting pattern is one of the important agronomic practices for increasing yield of row crop and reducing competition in environmental and soil resources. The response of groundnut to single -row and twin-row pattern has been investigated by many researchers. Gulluoglu et al. (2016) reported that twin row pattern increased yield (4906 kg ha^{-1}) from 80 cm × 25 cm × 80 cm ×30 cm (63.2 plants m^{-1}) than single row pattern with yield (35.7 plants m^{-1}).. The yield increase was however, 24.4% in twin row pattern than conventional single row pattern (standard). There is however, limited research conducted and little information available to compare the performance of newly released groundnut cultivars in terms of growth and yield as influenced by single and twin row pattern in the study area. The study therefore seeks to determine the effect of row pattern on growth, yield and yield components of two cultivars of groundnut in the forest-savannah transition zone of Ghana.

MATERIALS AND METHODS

Description of study area

Two field experiments were carried out at College of Agriculture Education of the University of Education, Winneba, Asante Mampong campus during 2017 and 2018 cropping seasons. The experimental site is gently incline and is well drained. The climatic conditions at the experimental sites for 2017 and 2018 cropping seasons is presented in Table 1.The climatic conditions during the field research periods show that differences in environmental factors (rainfall, temperature and relative humidity) were shown in both cropping seasons. The overall monthly rainfall during the 2017 cropping season was 512.4 mm and it occurred from May to August, 2017 with the peak in May and June (Meteorological Department- Mampong-Ashanti, 2017). The average monthly temperature of the experimental site for the 2017 cropping season was between 21.7 to 32.4°C, with the highest daily of 32.4°C occurring in May. The mean monthly relative humidity ranged from 63% to 97% with the highest occurring between June and July. In the 2018 cropping season, the overall monthly rainfall was 568.0 mm and it occurred from May to August with the peak in May and June (Meteorological Department- Mampong- Ashanti, 2018). The average monthly temperature of the experimental site for the 2018 cropping season was between 21.2 to 31.1°C, with the highest daily of 31.1°C occurring in May. The mean monthly relative humidity ranged from 65% to 92% with the highest occurring between May and June.

The soil at the experimental site has been categorized as Chronic Luvisol and locally as the Bediesi series with a pH range of 4.0-6.5 suitable for root, cereal, vegetable and legume crops production (Asiamah, 1988; FAO/UNESCO,1988) legend.

Experimental design and planting

The experimental design was a 2×4 factorial arranged in a Randomized Complete Block Design (RCBD) with three replications. The factors studied included: (A) Variety *(Yenyawoso* and *Adepa)* and (B) Row pattern and spacing (i) 50 cm × 10 cm single, (ii) 60 cm ×10 cm single row, (50 cm × 20 cm) ×20 cm twin row and (iv) (60 cm × 20 cm) × 20 cm twin row.

The total field size of 28.8 m × 13 m (374.4 m^2) was demarcated, cleared, lined and pegged and ridges prepared. Each experimental plot measured 2 m × 2 m, 2.4 m × 2 m, 2.8 m × 2 m and 3.2 m × 2 m, respectively based on the respective treatment. Each experimental plot had 120 plants based on row planting spacing and pattern. A space of 2 m was left between blocks with 1 m interval between plots. Two cultivars Yenyawoso and Adepa seeds obtained from Crops Research Institute (CSIR) in Kumasi, Ghana were used as a plant material in the study. Both cultivars have a semi-erect growth form with high oil content in the seed, high yield capacity and a growing period of between 60 to115 days. Three seeds of Yenyawoso and Adepa were planted per hill at a depth of 3-4 cm according to planting spacing and row patterns. Seedlings were thinned to 1 plant per hill 8 days after emergence. Each treatment plot had 4 rows on single row pattern with thirty plants on each row and eight rows on twin row pattern with fifteen plants on each row.

Table 1. Climatic data for 2017 and 2018 experimental periods.

Month	Total monthly rainfall (mm)		Mean monthly relative humidity (%) (Hours GMT)				Mean monthly temperature (°C)			
			06.00	06.00	15.00	15.00	Minimum		Maximum	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
May	161.2	184.6	95	91	63	65	23.6	22.9	32.4	31.1
June	175.0	185.5	97	92	70	73	23.0	22.5	30.6	29.7
July	139.3	157.2	97	89	75	73	21.8	22.0	29.2	29.8
August	51.8	40.7	96	86	73	71	21.7	21.2	27.2	28.3
Total	512.4	568.0								

Meteorological Department- Mampong-Ashanti, Ghana (2017, 2018).

Data collection and analysis

Data were collected on sixty plants from the two middle rows and the means were taken. The quantitative traits measured were number of branches per plant, plant height, number of plants harvested, number of pods per plant, 100-seed weight and pod yield (t ha^{-1}). Number of branches per plant was counted from the two harvestable areas. Plant height was measured on three plants from the two middle rows with meter rule. Number of plants harvested and number of pods per plant were counted from the two middle rows on the day of harvest. The 100-seed weight was determined by randomly sampling 100 - seeds from the two middle rows and the weight determined using electronic weighing scale. Data collected were subjected to ANOVA using GenStat Statistical Package, version 11.1. Least significant difference (LSD) was used to separate means at 5% level of probability.

RESULTS

Vegetative growth

Number of branches per plant

There was a significant difference between Adepa from Yenyawoso in terms of number of branches per plant for the entire 2017 and 2018 cropping seasons (Table 2a and b). The 50 cm × 10 cm and 60 cm × 10 cm single row pattern produced the same number of branches per plant at 30 days after planting (DAP) during the 2017 cropping season (Table 2a). The 50 cm × 10 cm and 60 cm × 10 cm single row pattern differed significantly from 50 cm × 20 cm × 20 cm and 60 cm × 20 cm × 20 cm twin row pattern in number of branches per plant at 30 DAP during the 2017 cropping season (Table 2a). The 60 cm × 10 cm single row pattern differed significantly from those planted on 50 cm × 20 cm × 20 cm and 60 cm × 20 cm × 20 cm twin row pattern in number of branches per plant for the entire growing period during the 2017 cropping season (Table 2a). There was no significant difference between variety × row pattern interaction in number of branches per plant in 2017 cropping season (Table 2a).The 50 cm × 10 cm differed significantly from other spacing at 30 DAP and 58 DAP in number of branches during the 2018 cropping season (Table 2b). There was no significant difference between single row and twin row pattern in number of branches per plant at 44, 72 and 86 DAP during the 2018 cropping season (Table 2b). There was a significant difference between variety × row planting spacing and pattern in number of branches per plant at 58 DAP and 86 DAP during the 2018 cropping season (Table 2b).

Plant height

There was a significant difference between Yenyawoso from Adepa in plant height at 44 DAP during the 2017 cropping season (Table 3a). However, Adepa had significantly taller plants from Yenyawoso at 86 DAP in the same cropping season. There was no significant difference between variety at 30 DAP and from 58 DAP to 72 DAP in plant height in 2017 cropping season (Table 3a). The 50cm x 10 cm single row pattern produced significantly taller plant than 50 cm x 20 cm x 20 cm and 60 cm ×20 cm ×20 cm twin row pattern at 30 DAP during the 2017 cropping season (Table 3a). There was no significant difference between row pattern in plant height from 44 DAP to 86 DAP at the same cropping period (Table 3a). There was no significant difference between variety x row pattern interaction in plant height for the entire 2017 growing period (Table 3a). There was a significant difference between Adepa from Yenyawoso in plant height at 30 DAP during the 2018 cropping season (Table 3b). However, Yenyawoso had significantly taller plants than Adepa from 44 DAP to 86 DAP in the same cropping season. There was no significant difference between single row pattern as well as with twin row pattern in plant height for the entire 2018 growing period (Table 3b). The 60 cm x 10 cm single row pattern produce significantly taller plants than 50 cm x 20 cm x 20 cm twin row pattern for the entire 2018 growing season. There was no significant difference between variety x row pattern interaction in plant height for the entire growing period in 2018 (Table 3b).

Yield and yield components

Number of plants harvested

Yenyawoso and Adepa had the same number of plants

Table 2a. Number of branches per plant as influenced by variety and row pattern- 2017 cropping season.

Treatment	30 DAP	44 DAP	58 DAP	72 DAP	86 DAP
Variety					
Adepa	6	8	10	12	13
Yenyawoso	5	6	8	10	10
Mean	5.5	7	9	11	11.5
LSD (P ≤ 0.05)	0.85	0.98	0.86	0.86	0.86
Row pattern					
50 cm × 10 cm	7	7	9	11	12
60 cm × 10 cm	7	8	10	12	13
50 cm×20 cm × 20 cm	5	6	8	10	11
60 cm × 20 cm × 20 cm	5	6	8	10	11
Mean	6	7	9	11	11.7
LSD (P ≤ 0.05)	1.2	1.39	1.22	1.22	1.22
Variety ×Row Pattern Interaction	NS	NS	NS	NS	NS

Table 2b. Number of branches per plant as influenced by variety and row pattern- 2018 cropping season.

Treatment	30 DAP	44 DAP	58 DAP	72 DAP	86 DAP
Variety					
Adepa	10	18	31	37	36
Yenyawoso	7	9	10	8	9
Mean	8.5	13.5	20.5	22.5	22.5
LSD (P ≤ 0.05)	1.48	2.22	1.83	3.47	2.75
Row pattern					
50 cm × 10 cm	10	14	20	20	22
60 cm × 10 cm	9	14	17	22	20
50 cm × 20 cm × 20 cm	7	12	20	24	25
60 cm × 20 cm × 20 cm	8	13	23	25	23
Mean	8.5	13.3	20	22.7	22.5
LSD (P ≤ 0.05)	2.09	NS	2.6	NS	NS
Variety x Row Pattern Interaction	NS	NS	3.67	NS	5.51

harvested and were not significantly different during the 2017 cropping season (Table 4). The 60 cm × 10 cm single row pattern and 50 cm × 20 cm × 20 cm twin row pattern had the same number of plants harvested and not significantly different in 2017 cropping season (Table 4). There was a significant difference between Yenyawoso from Adepa in number of plants harvested during the 2018 cropping season (Table 4). The 60 cm × 10 cm single row pattern differed significantly from 50 cm × 20 cm × 20 cm and 60 cm × 20 cm × 20 cm twin row pattern in number of plants harvested during the 2018 cropping season. There was no significant difference between variety x row pattern interaction in number of plants harvested.

Number of pods per plant

There was no significant difference between Adepa and Yenyawoso in number of pods per plant during the 2017 cropping season (Table 4). There was no significant difference between row pattern in number of pods per plant during the 2017 cropping season although differences exist between treatment (Table 4). Adepa

Table 3a. Plant height as influenced by variety and row pattern- 2017 cropping season.

Treatment	30 DAP	44 DAP	58 DAP	72 DAP	86 DAP
Variety					
Adepa	10.3	18.9	33.6	45.2	58
Yenyawoso	10	21.2	36.4	45.5	54.6
Mean	10.1	20	35	45.3	56.3
LSD (P ≤ 0.05)	NS	1.77	NS	NS	3.35
Row pattern					
50 cm x 10 cm	11.6	20	36.4	45.4	56
60 cm x 10 cm	10.6	19.4	35.2	46.7	56.3
50 cm x 20 cm x 20 cm	9.7	20.2	35.3	45.6	57.1
60 cm x 20 cm x 20 cm					
Mean	8.7	18.6	33.3	43.7	55.8
LSD (P ≤ 0.05)					
Variety x Row Pattern Interaction	10.1	20	35	45.3	56.3
	2.01	NS	NS	NS	NS
	NS	NS	NS	NS	NS

Table 3b. Plant height as influenced by variety and row pattern- 2018 cropping season.

Treatment	30 DAP	44 DAP	58 DAP	72 DAP	86 DAP
Variety					
Adepa	8.2	15	25.8	26.6	29.1
Yenyawoso	7.3	19.7	31.6	33.2	35.7
Mean	7.7	17.3	28.7	29.9	32.4
LSD (P ≤ 0.05)	0.77	1.58	4.49	2.88	3.12
Row pattern					
50 cm x10 cm	8.9	19.5	31.6	31.4	35.1
60 cm x10 cm	8.7	18.8	33.3	34	36.3
50 cm x 20 cm x 20 cm					
60 cm x 20 cm x 20 cm	7.2	17	27	29.3	31.4
Mean	6.3	14.2	22.8	24.9	26.9
LSD (P ≤ 0.05)					
Variety x Row Pattern Interaction	7.7	17.3	28.7	29.9	32.4
	1.09	2.24	6.35	4.07	4.42
	NS	NS	NS	NS	NS

differed significantly from Yenyawoso in number of pods per plant during the 2018 cropping season. There was no significant difference between 50 cm × 20 cm × 20 cm from 60 cm × 20 cm × 20 cm twin row pattern as well as between 50 cm × 10 cm and 60 cm × 10 cm single row pattern. There was a significant difference between 60 cm × 20 cm × 20 cm twin row pattern from 50 cm × 10 cm and 60 cm x 10 cm single row pattern. There was no significant difference between variety x row pattern interaction in number of pods per plant during the 2018 cropping season (Table 4).

100 - Seed weight

There was a significant difference between Adepa and Yenyawoso in 100 - seed weight in both 2017 and 2018 cropping seasons (Table 5). There was no significant difference between row pattern in 100 - seed weight although differences exist among treatments in both 2017 and 2018 cropping seasons (Table 5). There was no significant difference between variety x row pattern interaction in 100 - seed weight in both 2017 and 2018 cropping seasons (Table 5). Yenyawoso and Adepa

Table 4. Number of plants harvested and number of pods per plant as influenced by variety and row pattern- 2017 and 2018 cropping seasons.

Treatment	Number of plants harvested		Number of pods per plant	
	2017	2018	2017	2018
Variety				
Adepa	50	32	30	86
Yenyawoso	50	38	34	64
Mean	50	35	32	75.5
LSD (P ≤ 0.05)	NS	4	NS	11
Row pattern				
50 cm x 10 cm	48	38	27	64
60 cm x 10 cm	51	40	32	70
50 cm x 20 cm x 20 cm	51	34	35	82
60 cm x 20 cm x 20 cm				
Mean	50	29	34	86
LSD (P ≤ 0.05)				
Variety x Row Pattern Interaction	50	35.2	32	75.5
	NS	5.67	NS	15.5
	NS	NS	NS	NS

Table 5. 100 - seed weight (g) and Yield (t ha^{-1}) as influenced by variety and row pattern- 2017 and 2018 cropping seasons.

Treatment	100 - seed weight (g)		Yield (t ha^{-1})	
	2017	2018	2017	2018
Variety				
Adepa	70.4	76	3.94	5.86
Yenyawoso	56.4	69.2	3.73	5.12
Mean	63.4	72.6	3.83	5.49
LSD (P ≤ 0.05)	7.85	5.45	NS	NS
Row pattern				
50 cm x 10 cm	67.5	71.2	4.3	4.88
60 cm x10 cm	62.2	70.5	4.04	4.81
50 cm x 20 cm x 20 cm	63.7	73.3	3.71	6.7
60 cm x 20 cm x 20 cm				
Mean	60.3	75.3	3.29	5.58
LSD (P ≤ 0.05)				
Variety*Row Pattern Interaction	63.4	72.6	3.83	5.49
	NS	NS	NS	NS
	NS	NS	NS	NS

planted on both single and twin row pattern during the 2018 cropping season had heavier 100 - seed weight than those planted on same during the 2017cropping season (Table 5).

Yield (t ha^{-1})

The yield varies between 3.73 - 3.94 t $ha^{-1}$and 5.12 - 5.86 t ha^{-1} in variety and 3.29 -4.30 t ha^{-1} and 4.81 – 6.70 t ha^{-1} in row pattern during 2017 and 2018 cropping seasons respectively (Table 5). There was no significant difference between variety, row pattern and their interaction in yield during 2017 and 2018 cropping seasons although differences exist among treatment (Table 5). Adepa and Yenyawoso planted on both single and twin row pattern during the 2018 cropping season had higher yield than those planted on same during the 2017 cropping season

(Table 5).

DISCUSSION

Number of branches per plant

The significant difference between Adepa from Yenyawoso in number of branches per plant in both 2017 and 2018 cropping seasons could be due to differences in genetic traits. Onat et al. (2016) reported that peanut cultivars vary in growth habit and branching patterns ranging from the erect, semi-erect and runner types. The highest number of branches per plant in Adepa could also be attributed to presence of both primary and secondary branches produced coupled with more spreading nature of Adepa than Yenyawoso cultivar. This agrees with Konlan et al. (2013) in an observation made in northern Ghana that the improved variety, Adepa produced more number of branches per plant compared to other local varieties. The significantly higher number of branches per plant produced by 50 cm × 10 cm and 60 cm × 10 cm single row pattern than 50 cm × 20 cm × 20 cm and 60 cm × 20 cm × 20 cm twin row pattern and with 50 cm × 10 cm single row pattern than the other row patterns at 30 DAP and 58 DAP in 2017 and 2018 cropping seasons respectively could be due to narrow intra row spacing and pattern. Plant density is an important factor in plant growth. The closed intra row spacing and single row pattern might have led to early canopy closure at the early growth stage of plants resulting in vigorous plant growth with less competition for light and nutrients (Hamakareem et al., 2016). This is in disagreement with El Naim et al. (2010) Ansa (2016) that at close spacing the branches develop less in number than at wider spacing and that there is reduced vegetative and lateral development with closely spaced groundnut plants. Similar observation was made by Onat et al. (2016) that at low plant density, existing plants developed more branches because of reduced in competition. The significant effect between variety × row pattern interaction at 58 DAP and 86 DAP in number of branches during the 2018 cropping season could probably due to row pattern effect on variety coupled with higher rainfall and lower temperature experienced during the 2018 growing period compared to 2017 cropping period. Groundnut can be influenced by environmental factors such as soil moisture, temperature and plant density and that the growth and development is determined by the efficiency with which plant population uses available resources.

Plant height

The significant effect of Adepa and Yenyawoso in plant height during 2017 and 2018 cropping seasons could be attributed to differences in genetic characteristics of cultivars. Plant height is a growth parameter and can be influenced by both genetic and environmental factors such as soil moisture, nutrient, light and plant spacing. Both groundnut cultivars are semi-erect type as a genetic characteristics and their response to the environmental resources might have affected their growth differently. The variations in plant height observed in this study confirm the findings of Dapaah et al. 2014 and Konlan et al. (2013), who reported variations among cultivars in plant height. The significantly taller plants produced by 50 cm × 10 cm and 60 cm × 10 cm single row pattern than 50 cm × 20 cm × 20 cm and 60 cm × 20 cm × 20 cm twin row pattern at 30 DAP and for the entire growing season in 2017 and 2018 respectively could be attributable to close intra row spacing and single row pattern. This could be that the narrow spaced plants did not get enough space for lateral growth thereby compelled to grow more in vertical position to intercept light. Dapaah et al. (2014) similarly reported that at the high plant density, plants compete for light and grow taller, a phenomenon common with crowded plants. Under high planting density the competition for photosynthesis and nutrient absorption among plants become severe and the stem grows tall (Gulluoglu et al., 2016).

Number of plants harvested

The study revealed varying number of plants harvested among varieties, row pattern as well as between cropping seasons. In 2017 cropping season, Adepa and Yenyawoso produced the same (50.0) and higher number of plants harvested compared to 32 – 38 plants harvested during the 2018 cropping season. The higher number of plants harvested in 2017 cropping season could probably be influence of environmental conditions like plant population, soil moisture and light on cultivars. The efficiency with which plants use available environmental resources may determine the growth and yield (Onat et al., 2016). The significantly higher number of plants harvested with Yenyawoso than Adepa during the 2018 cropping season could be due to differences in genetic traits and its response to initial high rainfall experienced during the growing period. The significantly higher number of plants harvested by 60 cm x 10 cm single row pattern than 50 cm × 20 cm × 20 cm and 60 cm × 20 cm × 20 cm twin row pattern during the 2018 cropping season could be attributed to narrow spaced and, single row pattern. Narrow spacing probably encouraged upward growth of groundnut to intercept light for utilization and growth while single row probably minimized intra plant competition for water uptake, soil moisture and nutrient compared to twin row pattern with high population density per plot. This is in contrast with Konlan et al. (2013) and Dapaah et al. (2014) that groundnut grown on low plant densities, benefit from more water, solar energy and nutrition. The higher number of plants harvested during the 2017 cropping season than during the 2018 cropping season could be linked to tall plants produced in 2017. The close and positive relationship between the two groundnut varieties, row patterns in number of plants harvested and plant height during the 2017 growing season might have contributed to this observation. The tall plants produced might have enhanced light interception and utilization, hence high number of plants surviving until harvesting. Light interception is highly influenced by different planting patterns, and the more efficient capture and use of light contribute to yield advantages (Wang et al., 2017).

Number of pods per plant

The non-significant difference between varieties and row pattern in number of pods per plant during the 2017 cropping season could be that row pattern had no effect on variety. The significantly higher number of pods per plant produced by Adepa over Yenyawoso in 2018 cropping season could be due to differences in genetic trait and its response to high rainfall experienced during the growing period. The significant difference between 60 cm × 20 cm × 20 cm twin row pattern from 50 cm x 10 cm and 60 cm × 10 cm single row pattern in number of pods per plant could be attributed to wider spacing and twin row pattern. As the number of plants per unit area decrease, thus at low plant density competition for growth resources such as water, nutrient and light decrease. This is in conformity with earlier findings by Arioglu et al. (2017); Dapaah et al. (2014) and Konlan et al. (2013). Jaiswal et al. (2018) reported that wider spacing of 30 cm × 15 cm proved superior in increasing number of pods per plant than closer spacing of 22.5 cm × 10 cm. Wider spacing might have decreased inter and intra-specific competition for crop growth resources compared to narrow spaced plant. Crop yield is determined by the efficiency with which plant population use available environmental resources such as nutrient, light and water for growth (Onat et al., 2016; Angelucci and Bazzuchi, 2013).

Total yield (t ha^{-1})

The higher yield produced in both cultivars and row pattern during the 2018 cropping season than in 2017 could be due to high rainfall experienced during the 2018 cropping period. Seasonal changes to rainfall could lead to changes in soil water content, which is likely to affect plant growth and yield. The higher rainfall experienced in 2018 than in 2017 cropping seasons might have enhanced plants to produce more leaves, large leaf area and canopy spread to maximize light interception during growth and reproductive stages for high yield. Lack or inadequate rainfall during flowering and pod setting causes substantial decrease in yield. The production of high yield in Adepa than Yenyawoso in both 2017 and 2018 cropping seasons may be linked to high production of number of branches per plant in Adepa at 86 DAP. This agrees with Dapaah et al. (2014) that nodes of branches are potential sites for peg development and subsequent pod formation and that branching characteristics is an important agronomic traits for crop yield. Konlan et al. (2013) reported higher yield in Adepa than other four groundnut varieties in northern Ghana The higher yield in 50 cm × 20 cm × 20 cm twin row pattern during the 2018 cropping season than same during the 2017 cropping season and the other row patterns may be attributed to wider spacing and twin row pattern. Wider spacing might have decreased inter and intra plant competition for resources such as moisture, nutrient and light. This agrees with Arioglu et al. (2017) and Onat et al. (2016). Planting spacing, row pattern, plant density and branching are some of the most important factors that may have direct influence on crop yield. There was a close and positive relationship with number of branches per plant at 86 DAP and pod yield with 50 cm × 20 cm × 20 cm twin row pattern in 2018 cropping season. Branching in groundnut may impact positively on yield since the branches bear the leaves and also determine the canopy spread and closure and solar interception and utilization (Dapaah et al. (2014). This is in support of Onat et al. (2016) that at low plant density, existing plants developed more branches and pegs because of reduction in competition.

100 - Seed weight

Adepa produced significantly higher 100 - seed weight than Yenyawoso in both cropping seasons. This might be due to differences in genetic characteristics. Konlan et al. (2013) earlier reported that Adepa with bunch semi-erect growth habit produced heavier 100- seed weight than other local varieties which were of the bunch semi-erect types. The 50 cm × 20 cm × 20 cm and 60 cm × 20 cm × 20 cm twin row pattern produced heavier 100 - seed weight than 50 cm x 10 cm and 60 cm x 10 cm single row pattern during the 2018 cropping season. This might probably be due to the highest number of pods per plant produced. There was a close and positive relationship between number of pods per plant and 100 - seed weight during the 2018 cropping season. The low plant density might have contributed to decreased inter and intra-specific competition for growth resources and compensated for by the increased pods number per plant giving high 100 - seed weight. Increased in 100 - seed weight with decreased plant density with wider spacing have also be reported by Dapaah et al. (2014) and Konlan et al. (2013). The variety x row pattern interaction effects for 100 - seed weight was not significant in both years.

Conclusion

In conclusion groundnut can be cultivated in the forest-savannah transition zone of Ghana for high vegetative biomass, pod yield and heavy seeds. Farmers are encouraged to grow preferably Adepa cultivar of groundnut under initial high rainfall condition for proper crop growth in terms of high number of branches and tall plants and also for high yield. Groundnut should be planted using 50 cm × 20 cm × 20 cm and 60 cm × 20 cm × 20 cm twin row pattern for high vegetative biomass, yield and quality seeds in terms of heavy seeds. Interaction effect between variety × row pattern was significant with number of branches per plant at 58 DAP and 86 DAP during the 2018 cropping season. This is an indication that row pattern had effect on variety and with higher rainfall and lower temperature experienced during the 2018 growing period compared to 2017 cropping period the growth of more branches per plant was enhanced. Nodes on branches are the potential sites for peg development and subsequent pod formation hence high yield in groundnut. Groundnut can be influenced by environmental factors such as soil moisture, temperature and plant density and that the growth and development of a crop is determined by the efficiency with which plant population uses available resources.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Angelucci F, Bazzuchi A (2013). Analysis of incentives and disincentives for groundnuts in Ghana. Technical notes series, MAFAP, FAO, ROME. www.fao.org/publications

Ansa JEO (2016). Effects of groundnut spacing on yield and weed control in the rainforest agro-ecological zone of Nigeria. Direct Research Journal of Agriculture and Food Science 4(12):374-377.www.researchgate.net.http://directresearchpublisher.org/aboutjournal/drjafs.ISJN-ISJN:A4372-2604

Arioglu H, Kurt C, Bakal H, Gulluoglu L (2017). The effect of twin row planting pattern and plant population on yield and yield components of peanut (*Arachis hypogaea* L.) at main crop planting in Cukurova Region of Turkey. Turkey Journal of Field Crops 22(1):24 31.

Asiamah RD (1988). Soils and soil suitability of Ashanti region. Soil Research Institute –Council for Scientific and Industrial Research, Kwadaso-Kumasi. Report No. l93 P 21.

Dapaah KH, Mohammed I, Awuah RT (2014). Phenological development and yield of three groundnut varieties as influenced by plant density in a forest savannah transition zone. International Journal of Agriculture Research 9(2):87-98.

El Naim AM, Eldouma MA, Abdalla AE (2010). Effect of weeding frequencies and plant density on the vegetative growth characteristics in groundnut (*Arachis hypogaea* L.) in North Kordofan of Sudan. International Journal of Applied Biology and Pharmaceutical Technology1(3):1188-1193.

Food and Agricultural Organization (FAO) (2008). FAOSTAT.Retrieved on 10 April, 2017.http:// faostat.fao.org/faostat/.

FAO/UNESCO (1988). Food and Agricultural Organization/United Nations Educational and Scientific and Cultural Organization. Soil map of the World. Revised legend.Rome: FAO.

Gulluoglu L, Bakal H, Arioglu H (2016). The effects of twin-row planting pattern and plant population on seed yield and yield components of soybean at late double - cropped planting in Cukurova Region. Turkish Journal of Field Crops 21(1):59-65.

Gulluoglu L, Bakal H, Onat B, Kurt C, Arioglu H (2016a). Characterization of peanut (*Arachis hypogaea* L.) seed oil and fatty acids composition under different growing Mediterranean environment. Journal of Experimental Biology and Sciences 4(5S):564-571.

Gulluoglu L, Bakal H, Onat B, Arioglu H (2016b).The effect of twin-row planting pattern and plant population on yield and yield components of peanut (*Arachis hypogaea* L.) at main crop planting in Cukurova Region of Turkey. Turkish Journal of Field Crops 22(1):24-31

Gulluoglu L, Bakal H, Onat B, Kurt C, Arioglu H (2016 c). The effects of harvesting on some agronomic and quality characteristics of peanut grown in the Mediterranean region of Turkey. Turkish Journal of Field Crops 21(2):224-232.

Hamakareem HF, Hamahasan BM, Ali SHS (2016). Influence of plant spacing on the growth and yield of groundnut (*Arachis hypogaea* L.). International Journal of Current Research in Biosciences and Plant Biology 3(10):7-12.

Jaiswal AB, Gourkhede PH, Narale SH (2018). Studies of different plant geometry on yield and qualityof groundnut genotypes drought prone area of Marathwada region. International Journal of Chemical Studies 6(2):312-316.

Knezevirc SZ, Evans SP, Mainz M (2003). Row spacing influences the critical timing for weed removal in soyabean (*Glycine max*). Weed Technology17(4):666-673.

Konlan S, Sarkodier – Addo J, Asare E, Kombiok MJ (2013). Groundnut (*Arachis hypogaea* L.) varietal response to spacing in the Guinea Savannah agro-ecological zone of Ghana: Nodulation and Nitrogen fixation. Agriculture and Biology Journal of North America 4(3):324-335.

Konlan S, Sarkodier – Addo J, Asare E, Kombiok MJ (2013). Groundnut (*Arachis hypogaea* L.) varietal response to spacing in the Guinea Savannah agro-ecological zone of Ghana: Growth and Yield. African Journal of Agricultural Research 8(22):2769-2777.

Martey E, Wiredu AN, Oteng-Frimpong R (2015). *Baseline study of groundnut in Northern Ghana,* LAP Lambert academic publishing.

Meteorological Department (2017). Weather forecast for Mampong-Ashanti, Ghana. https://www.yr.no/en/forecast/daily-table/2-22898264/Ghana/Ashanti/Mampong; https://www.yr.no/place/Ghana/Ashanti/Mampong

Meteorological Department (2018). Weather forecast for Mampong-Ashanti, Ghana. https://www.yr.no/en/forecast/daily-table/2-22898264/Ghana/Ashanti/Mampong; https://www.yr.no/place/Ghana/Ashanti/Mampong

Onat B, Bakal H, Gulluoglu L, Arioglu H (2017). The effect of row spacing and plant density on yield and yield components of peanut grown as a double crop in Mediterranean environment in Turkey. Turkish Journal of Field Crops 22(1):71-80.

Wang ZK, Zhao XN, Wu PT, Gao Y (2017). Border row effects on light interception in wheat/maize strip intercropping systems. Field Crops Research 214:1-13.

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Yield evaluation and character association of linseed (*Linum usitatissimum* L.) genotypes in moisture stress areas of South Tigray, Ethiopia

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Linseed (*Linum usitatissimum* L.) is one of the most important highland oil crops of southern Tigray, Ethiopia and it is considered as the least expensive source for oil related home consumptions. The 12 genotypes of linseed including two standard checks were evaluated in the highland and moisture stress area of Southern Tigray under rain fed condition with the objective of evaluating yield and yield components as well as their association. Observations were recorded for different characters, viz., days to maturity, plant height, and number of capsules per plant, number of seeds per capsule, 1000-seed weight and seed yield. Highly statistical significant (P < 0.01) differences were found among the genotypes for days to maturity, plant height and seed size. The standard checks (Bekoji and Kassa -2) were matured late (122 days after emergence) in the growing area as compared with the other genotypes. These genotypes had long plant height (89.4 and 87.3 cm, respectively) and they showed higher significant difference. Genotypes 20-Marc, 8-Marc, 4-Marc, 11-Marc and 31-Marc were matured with in 103, 104, and 105 days in that order and they were earlier as compared to others. Mean seed yield had positive correlation with all yield components except 1000 seed weight. Significantly higher positive significant correlation was observed among days to maturity and plant height (r= 0.73). Plant height also showed positively and significantly correlation with seed weight (0.54). Therefore, strong and positive association between seed yield and some of yield related traits provide the opportunity to improve seed yield and other desirable traits of linseed.

Key words: Correlation, genotype (entry or variety), linseed, yield component.

INTRODUCTION

Linseed (2n = 30) is an important oilseed and fiber crop which belongs to the family Linaceae (as cited by Mulusew et al. (2013). It is believed that this crop species may have originated from *Linum angustifolium* Huds. (2n = 30) native to the Mediterranean region (Cooke, 1903; Legesse, 2010). Linseed is an annual field crop that is largely grown in temperate areas of the world (Mansby et al., 2000) and cool tropics including highland areas of

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Ethiopia with its altitude ranging from 2500 m. above sea level and more. It is the second most important oil crop in the highlands of Ethiopia in terms of area coverage and production (Adefris et al., 1992; Adugna, 2000). Linseed requires cool temperatures ranging from 10 to 30°C although the crop grows best within 21 and 22°C during its growing period to produce good yields. According to Adugna (2007), Ethiopia is considered to be the secondary center of diversity, and now the 5th major producer of linseed in the world after Canada, China, United States and India. The crop performs best in altitudes ranging from 2200 to 2800 meters above sea level (Reta and Nigussie, 2017). The wide range of agro-climatic conditions in Ethiopia may have contributed to its wider diversification for this oil crop. In the 2015/2016 cropping season, 85,415.67 ha of land was covered in Ethiopia with linseed and the production was estimated to be 885,511.44 quintals (MoANR, 2016).

In Ethiopia, linseed has been cultivated primarily for seed and oil purposes. Linseed oil content is mainly in the range of 35 - 44% with drying oil properties (Tesfaye et al., 2016). The seed is commonly roasted, ground and mixed with spices and some water to be served along with local breads. It also consumed in soups, soft drinks and with porridgesor cooked potatoes. Its industrial use is higher than all other oil crops. It has traditionally been used for food and as a cash crop since ancient times. Its seeds are usually roasted, ground, mixed with spices and water, and served with various local consumptions. Linseed oil has been used for edible purpose in the past years.

The ground seed is of great value for a number of purposes including gastric pain and the extracted mucilage is used in cosmetic and pharmaceutical industries (Hiruy and Nigussie, 1988). The oil is also used as a raw material for a number of industrial products, such as drying agents, paintings and varnishes, soap manufacture, printing inks etc., whereby it lends itself as an export commodity, thus, contributing a lot towards building the national economy (Reta and Nigussie, 2017)

The highland areas of Southern Tigray are one of the potential areas for the production of highland oil crops in Ethiopia, and linseed is the only main oil crop grown in the area. Despite its potential and profitability, the crop has been traditionally grown on marginal lands using local variety. No improved linseed variety has been grown in the area and the locally cultivated accessions (land races) are not yet collected and tested for their yield potential and other yield components. On the contrary, there is a sever shortage of edible oil in the country (Ethiopia) in general and the Tigray region in particular. Hence, the objective of this study is to evaluate the overall performances of the locally collected accessions (landraces) and released linseed varieties to increase the production and productivity of the crop and contributes to minimize the edible oil shortage in the country as well as to exploit the linseed production capacity for domestic uses and export purposes.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted in the field of farmers' training center found at Mekhan kebelle of Endamekhoni district, Southern Tigray, Ethiopia during the main cropping season of 2019. Mekhan FTC is located at the distance of 660 km from Addis Ababa (the capital city of Ethiopia) and 125 south of Mekelle. This center is also found at about 12°33'21" N latitude, 39°25'28" E longitude and at an altitude of about 2480 m above sea level (Amanuel et al., 2015). The area is characterized by moisture stress agro-ecology but bimodal rainfall pattern. According to Amanuel et al. (2015), the minimum and maximum annual temperature of the study area is 8-25°C, respectively and the annual rainfall distribution ranges from 600 - 800 mm,

Experimental materials

Twelve entries (genotypes) of linseed including two standard checks were collected from Tigray region and evaluated in the study area. The experiment was laid out in a randomized complete block design with three replications. The plot size was 1.2 × 5 m with spacing of 20 cm between rows and drilling method of sowing. The four central rows were used for data collection and all agronomic practices were done as per the recommendations.

Collected data and analysis of variance

The yield and yield component parameters were collected that include days to physiological maturity, plant height, number of capsules per plant, number of seeds per capsule, 1000 seeds weight and seed yield. The collected data were analyzed using the standard procedure applicable to randomized complete block design as suggested by Gomez and Gomez (1984) using GenStat (Payne et al., 2007) version 16 software programs and least significance difference was used for the mean comparison both at 1 and 5% probability level.

RESULTS AND DISCUSSION

Analysis of variance and estimation of variance components

The mean days to maturity, 1000 seed weight, plant height, number of capsules per plant, number of seeds per capsule and seed yield were analyzed. A higher significant ($P < 0.01$) difference was observed on the genotypes for days to maturity, plant height and thousand seed weight (Table 1). This finding is in consistent with Tesfaye et al. (2016). Non -significant ($P > 0.05$) differences were observed among the genotypes for seed yield, number of capsules per plant and number of seed per capsule.

The standard checks (Bekoji and Kassa -2) matured late (122 days after emergence) in the growing area as compared with the other genotypes. However, genotypes 20-Marc, 8-Marc, 4-Marc, 11-Marc and 31-Marc matured

Table 1. Mean Seed yield and other agronomic characters of linseed genotypes.

Genotype	DM	PHT (cm)	NCPP	NSPC	TSW (g)	SY ($kgha^{-1}$)
20-Marc	103	62.0	32	7.9	4.933	1980
8-Marc	104	61.5	25	7.8	4.667	1836
4-Marc	105	64.3	31	9.0	5.200	1910
11-Marc	105	61.3	28	8.3	5.267	1698
31-Marc	105	60.9	27	8.1	4.933	1865
19-Marc	108	64.1	33	8.1	4.867	1950
234008t	112	68.1	23	8.5	4.400	1945
22-Marc	113	61.6	25	8.0	4.867	1997
28-32 Marc	115	68.0	23	8.5	4.533	2194
237001	116	65.5	30	8.3	4.400	2167
Bekoji	122	89.4	31	7.5	5.667	2182
Kassa-2	122	87.3	25	7.7	5.733	1836
Mean	110.7	67.8	28	8.1	5.0	1963
LSD (5%)	4.316**	8.312**	NS	NS	0.542**	NS
CV (%)	2.3	7.2	21	6.9	6.5	14.8

NS = Non-significant difference, DM = Days to maturity, PHT = Plant height, NCPP = Number of capsules per plant, NSPC = Number of seeds per capsule, TSW = Thousand seed weight, SY = Seed yield.

within 103, 104, and 105 days in that order and they were earlier in days to maturity. In similar manner, both the standard checks varieties had long plant height (89.4 and 87.3 cm) and they showed highest significant ($P < 0.01$) difference with the other genotypes (Table 1).

Performance of seed yield and seed size of linseed genotypes

The seed yield has revealed that no significant ($P > 0.05$) variation was observed among the genotypes of linseed. However, numerically genotypes 28-32 Marc, Bekoji, and 237001 gave higher seed yield as 2194, 2182, 2167 kg ha^{-1}, respectively. The character tested previously in Ethiopia and other countries, the mean seed yield obtained in this research is higher and very appreciable even in most or all tested materials. For example in Ethiopia, lower seed yield is recorded in different research results conducted and displayed by various professionals (Tesfaye et al., 2016; Lirie et al*.,* 2013; Abebe et al., 2010; Yared and Miteru, 2016). This could be related to the suitability of the agro-ecology of the area to these tested and higher yielder genotypes. Very high significant ($P < 0.01$) difference was observed among the tested linseed genotypes for seed size (Table 1). The Bekoji, Kassa-2, 11-Marc and 4-Marc gave highest and similar 1000 seed weight (5.733, 5.667, 5.267 and 5.201 g, respectively) and there was non-significant difference among the genotypes. On the other hand, even though they showed similar p-value with some other genotypes, entry 237001 and 234008t scored lowest seed weight (4.400 g 1000^{-1}).

Correlation of seed yield with other characters

Correlation coefficient estimates degree of association of different linseed yield and yield components among themselves. Based on this, the values of Pearson correlation coefficient revealed that days to maturity and plant height showed highly significant and positive correlation (0.73). This situation was observed in Bekoji and Kassa-2 genotypes which had long plant height as a result of late days to maturity. This result is in consonance with Yared and Miteru (2016) and Reddy et al*. (*2013). Mean plant height had significant positive correlation with number of capsules per plant. Similar findings were reported by Dashe et al*.* (2016), Naik and Satapathy (2002) and Savita (2006).

Even though there was no significant correlation of seed yield with days to maturity, number of capsules per plant, number of seeds per capsule and plant height, the relationship was positive (Table 2). Similar results were reported by Dash et al *(*2016); Tesfaye et al. (2016) and Tadesse et al. (2009). Therefore, number of seeds per capsule (0.114), days to maturity (0.18) and plant height (0.19) showed a low positive direct effect on the seed yield genotypes (Ibrar et al., 2016).

On the other hand, seed yield has negative correlation with 1000 seed weight in very low amount ($r = -0.0896$). This result is in agreement with Yadav et al. (2017) and Dash et al*. (*2016). Thousand seed weight has significant and positive association ($r = 0.5358$) with plant height but non-significantly correlation with days to maturity and number of capsules per plant ($r = 0.27$ and 0.28, respectively). The 1000 seed weight correlates with number of seeds per capsule negatively ($r = -0.33$), that

Table 2. Correlation coefficients among the traits measured from twelve linseed genotypes.

Trait	DM	PHT	NCPP	NSPC	TSW	SY
DM	-					
PHT	0.7283	-				
NCPP	-0.0764	0.0125	-			
NSPC	-0.1394	-0.2024	-0.0308	-		
TSW	0.2664	0.5358	0.2762	-0.3329	-	
SY	0.2233	0.2593	0.2278	0.0181	-0.0847	-

DM = Days to maturity, PHT = Plant height, NCPP = Number of capsules per plant, NSPC = Number of seeds per capsule, TSW = Thousand seed weight, SY = Seed yield.

is, a decrease was observed in seed weight with increasing number of seeds per capsule. Dash et al. (2016) and Mahto and Rahaman (1998) found negative correlation with number of seeds per capsule and 1000-seed weight. The mean number of capsules per plant had positive but non-significant difference correlation with plant height and 1000-seed weight. This is in consonance with the findings of Savita (2006). The number of seeds per capsule negatively correlates with most traits, that is, with days to maturity, number of capsules per plant, plant height, and seed size but only positively correlated with seed yield. Also Mahto and Rahaman (1998) and Naik and Satapathy (2002) had result similar with this result. The strong and positive association between seed yield and some of yield related traits provides the opportunity to improve seed yield and other desirable traits simultaneously. Linseed traits that did not have significant correlation with seed yield indicate that selection for increased levels of these traits may not bring significant change in seed yield

Conclusion

The days to maturity is an important parameter for the study areas as the testing location is characterized by moisture stress condition. Genotypes 20-Marc and 8-Marc showed earlier days to maturity with their reasonable seed yield and breeders should consider not only to seed yield but also to earlier physiological maturity of linseed entries selection. The yield components which include number of capsules per plant, number of seeds per capsule, plant height and seed size are the important selection parameters to improve linseed yield. Almost all of the above traits correlate positively with seed yield because these parameters had positive direct effect on the seed yield as their correlation values were in the positive direction.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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REFERENCES

Abebe D, Choferie A, Aka E (2010). Registration of Kulumsa-1 Linseed (Linum usitatissimum L.) Variety. East African Journal of Sciences 4(2):123-127

Adefris TW, Getinet A, Tesfaye G (1992). Linseed breeding in Ethiopia. In: Oilseeds Research and Development in Ethiopia. Proceedings of the First National Oilseeds Workshop 3-5 Dec. 1991. IAR, Addis Ababa, Ethiopia, pp. 41-50.

Adugna W (2007). Linseed (Linum usitatissimum L.). In: van der Vossen, H.A.M. and Mkamilo, G.S. (eds.). Vegetable oils and fats, Plant Resources of Tropical Africa (PROTA) no. 14, PROTA foundation, Wageningen, the Netherlands, pp. 108-115.

Adugna W (2000). Assessment of tissue culture drived regenerants of linseed (Linum usitatissimum L.) in Ethiopia. Unpublished M.Sc. thesis, University of the Free State, Bloemfontein, South Africa.

Amanuel Z, Gebresamuel G, Girma A (2015). Characterization of Agricultural Soils in CASCAPE Intervention Woredas in Tigray Region, Mekelle, Ethiopia

Cooke T (1903). Flora of the Presidency of Bombay. Biodiversity Heritage. Red Lion Court, Fleet Street, London. www.Biodiversitylibrary.org.

Dash J, Sen BN, Ballav UM (2016). Variability, correlation and path-coefficient analysis in linseed (Linum usitatissimum L.) under late sown conditions in the north central plateau zone of Odisha in India. International Journal of Advanced Research 4(1):799-811 ISSN 2320-5407.

Gomez KA, Gomez AA (1984). *Statistical Procedure for Agricultural Research* (2nd ed.). John Wiley and Sons, New York.

Hiruy, B., & Nigussie, A. (1988, January). Verification of improved linseed production practices on farmers' fields. In Oil crops: sunflower, linseed and sesame. Proceedings of the fourth oil crops network workshop, Njoro, Kenya.

Ibrar D, Ahmad R, Mirza Y, Mahmood T, Ahmad MK, Shahid MI (2016). Correlation and Path Analysis for Yield and Yield Components in Linseed (Linum usitatissimum L.). Journal of Agricultural Research 54(2):153-159.

Legesse B (2010). Genetic Diversity Study of Linseed Genotypes on Acidic Soil at Bedi Trial Site, Central Highland of Ethiopia, MSc.Thesis. Addis Ababa University, Addis Ababa.

Lirie E, Zeleke H, Wakjira A (2013). AMMI analysis of yields and oil content in some linseed (Linum usitatissimum L.) genotypes in south and central Ethiopia. Ethiopian Journal of Agricultural Sciences 24(1):79-98.

Mahto C, Rahaman MH (1998): Correlation and path analysis of some quantitative characters in linseed. Journal of Oilseeds Research 15(2):348-351.

Mansby E, Díaz O, von Bothmer R (2000). Preliminary study of genetic diversity in Swedish flax (Linum usitatissimum). Genetic Resources and Crop Evolution 47(4):417-424.

MoANR (2016). Plant Variety Release, Protection and Seed quality Control Directorate. Crop Variety Register, Issue No. 19. Addis Abeba, Ethiopia. pp. 140-143

Mulusew F, Mekbib F, Wakjira A (2013). Seed oil diversity of Ethiopian linseed (*Linum usitatissimum* L.) landraces accessions and some exotic cultivars. [online]. African Journal of Biochemistry Research. Available from: http://www.academicjournals.orgAJBR. [Date accessed: 21 Dec 2019]. ISSN 1996-0778, 7(6):76-85,

Naik BS, Satapathy PC (2002). Selection strate sy for improvement of seed yield in late sown linseed. Research on Crops 3(3):599-605

Payne RW, Murray DA, Harding SA, Baird DB and Souta DM (2007). GenStat for Windows ® (12th Edition) Introduction. VSN International, Hemel Hempstead, UK.

Reddy MP, Rajasekhar BR, Arsul BT, Maheshwari JJ (2013). Character Association and Path Coefficient Studies in Linseed**.** International Journal of Current Microbiology and Applied Sciences 2(9):250-254. http://www.ijcmas.com

Reta D, Nigussie D (2017). Effect of Nitrogen and Sulphur on Nitrogen and Sulphur Uptake in Linseed (Linumusitatissimum L.) in Sinana, Southeastern Ethiopia. International Journal of Applied Agricultural Sciences 3(5):111-116

Savita SG (2006): Diversity of linseed germplasm for yield and yield components. M. Sc. (Ag.) Thesis, University of Agricultural Sciences, Dharwad, India.

Tadesse T, Singh HARJIT, Weyessa B (2009). Correlation and Path Coefficient Analysis among Seed Yield Traits and Oil Content In Ethiopian Linseed Germplasm. International Journal of Sustainable Crop Production 4(4):08-16

Tesfaye W, Anley W, Habtie F (2016). Participatory Evaluation of Improved Varieties of Linseed in Dabat District, Northwest highland of Ethiopia. [online]. International Journal of Life Sciences 4(3):100-105.

Yadav PC, Yadav RK, Vishwanath, Panday Y and Kuma S (2017). Stability and correlation analysis for yield and its component traits in linseed (Linum usitatissimum L.). Journal of Pharmacognosy and Phytochemistry, pp. 274-277

Yared S, Misteru T (2016). Genetic Variability and Correlation Analysis of Ethiopian Linseed (Linum usitatissimum L.) Accessions. Molecular Plant Breeding 7(22):1-5 (doi: 10.5376/mpb.2016.07.0022).

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Effect of germination on structural and physicochemical properties of starch in glutinous brown rice

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This study compared the structural and rheological properties of native (GB0), 12 h (GB12), 24 h (GB24), 36 h (GB36), 48 h (GB48) and 72 h (GB72) germinated glutinous brown rice starch to improve the market value of glutinous rice through germination. The proportion of A chains (DP 6-12) increases and the proportion of B_1 chains (DP 13-24) decreased with germination time. Interestingly, we observed that the total proportion of B_2 and B_3 chains decreased, but was recovered after germination at 36 h. The effect of germination on the distribution of amylopectin length results in a decrease in relative crystallinity, gelatinisation temperature, gelatinisation enthalpy and pasting viscosities. In this study, we found that GB12 starch gel has the weakest thermal stability and its shear resistance is more difficult to retrogradation; while GB36 has the highest chain association (retrogradation) which is induced by cooling.

Key words: Glutinous brown rice, germination, starch, structural properties, rheological properties.

INTRODUCTION

Glutinous rice commonly referred to as sticky or waxy rice is characterised by its non-transparent surface and high amylopectin content. Such rice is widely processed into food products and has a high yield, particularly in China, where it is mainly used as material of traditional foods, such as Tangyuan, Zongzi, and Shaoxing wine, and as an added ingredient in other products. Glutinous rice starch is almost entirely amylopectin, with <2% amylose (Xu et al., 2013). The amylose–amylopectin ratio will influence the physicochemical properties of starch. Amylopectin exhibits poor syneresis and hard to retrogradation. As a result, compared with the boiled rice from a normal-amylose cultivar, the low-amylose cultivar is stickier (Noda et al., 2003). The crystallization of amylopectin in high-amylopectin cultivars will also contribute to their resistance to enzymatic digestibility (Liu et al., 1999). Consequently, such cultivars result in indigestion and are not suitable as staple food, resulting in a much lower market value.

Compared with ordinary milled rice grains, brown rice grains are nutrient-rich, for example dietary fibres, vitamins, phytic acids, gamma aminobutyric acid, and

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vitamins, etc (Komatsuzaki et al., 2007). Because of the highly nutritional value of GBR, its products are popularity in health-conscious consumers in Asian. Despite its elevated nutritional content, brown rice is not acceptable as table rice because of its poor water absorbency, expansibility in cooking, and poor texture. The rich tough of out bran layer keeps off water into the endothecium of GBR, and leads to these shortcomings (Das et al., 2008). For this reason, the characters of brown rice have been improved by several new processing methods which developed in recent years, covering high hydrostatic pressure (Boluda-Aguilar et al., 2013; Xia et al., 2017; Wang et al., 2020), high-temperature fluidization (Jaisut et al., 2009), ultrasound (Cui et al., 2010), low-pressure plasma (Chen et al., 2016), and germination. During the process of germination, the degradation of high-molecular-weight polymers will result in generation of biofunctional substances and improved organoleptic qualities, resulting in a softened texture and increased flavour (Subba Rao and Muralikrishna, 2002). Starch accounts for about 90% of the total dry weight of rice, and the ease with which rice cooks and its overall taste is primarily affected by its starch properties. Amylopectin was the main component of most starches, and variations in the amylopectin fine structure will lead to different physicochemical properties. Many studies have examined the different characteristics between germinated and ungerminated brown rice starch (Xu et al., 2012; Musa et al., 2011). Pinkaew et al. (2016, 2017) only investigated the characteristics of the pre-germination stage of brown rice starches. Several researches have evaluated the impact of germination on the physiochemical properties of long-grain or round-grain brown rice starch (Wu et al., 2013; Li et al., 2017; Kalita et al., 2017). However, less research has been conducted to specifically examine germinated glutinous brown rice starch. The physicochemical properties of glutinous brown rice starch from germination at 36 h have only been evaluated by You et al. (2016), who examined the structural properties and the *in vitro* digestibility of native and 36-h germinated waxy brown rice starches, whereas other germination stages were not studied.

The aim of the present study was to compare the structural and rheological properties of glutinous brown rice starch at 0-72 h germination stages. Figure 1 These findings can help to (1) understand the effects of different germination time on the structural and physicochemical properties of starch, and (2) improve the texture and organoleptic qualities of glutinous brown rice through germination, and (3) provide a basis for the development of glutinous brown rice, and a reference for more effective use of germinated glutinous brown rice as an additive.

MATERIALS AND METHODS

Glutinous brown rice was harvested in 2019 and provided by Anhui Guangming Huaixiang Industry and Trade Group Co., Ltd (Anhui province, China), and stored at 4°C in a refrigerator.

Preparation of germinated glutinous brown rice

The glutinous brown rice grains (2000 g) were thoroughly rinsed with tap water and disinfected with 1% NaClO, followed by soaking in distilled water (pH=7, grain to water ratio 1:2 w/v) at 25°C for 12 h; the distilled water was changed every 2 h. The rice grains were placed between wet gauze and sponge on a tray after soaking, then germinated in a constant temperature incubator (DHP-9162, Yiheng technology Co., Shanghai, China) for 72 h at 35°C and 65% humidity. The sample was obtained every 12 h. After germination for regular time, the native and germinated glutinous brown rice were dried at 45°C for 24 h.

Isolation of starch

The starch of the native glutinous brown rice (GB0), 12 h germinated glutinous brown rice (GB12), 24 h germinated glutinous brown rice (GB24), 36 h germinated glutinous brown rice (GB36), 48-h germinated glutinous brown rice (GB48) and 72 h germinated glutinous brown rice (GB72) were isolated by soaking in 0.1% NaOH solution using the procedure proposed by Lim et al. (1999). The extracted starches were continuously dried at 45°C for 1 d, and ground into powder by using a mechanical grinder (DSY-9002, Jiushunying Chamber Commerce Co., Zhejiang, China) and then passed through a 100-mesh sieve.

Amylopectin branch chain length distributions

The branch chain length distribution of the starches was determined by high performance anion exchange chromatography-pulsed amperometric detector (HPAEC–PAD). Sample (9 mg) was dissolved in 100% DMSO (450 μL) and stirred in a boiling water bath for 12 h. The starch solution was diluted with ultrapure water (2250 μl) and 300 μl of sodium acetate buffer (0.1 M, pH 4.5). Next, 1 μl of isoamylase and 1 μl of pullulanase were added to the sample solution and then stirred (100 rpm) at room temperature for 12 h. The enzymatic reaction was terminated by heating in a boiling water bath. After debranching, the sample solution was centrifuged and filtered through 0.45 μm nylon syringe filter before being injected into the HPAEC system (ICS5000, Dionex, CA, USA); it was injected with Pulse ampere detector (PAD), using 150 mM NaOH and 500 mM sodium acetate in 150 mM NaOH at a flow rate of 1 mL/min to gradient elution separation.

X-ray diffraction

X-ray diffraction patterns were obtained by an X-ray diffractometer (X'Pert PRO, Philips Co., Almelo, Netherlands) which operated at 40 mA and 40 kV with scanning speed of 2.0°/min and scanning range of 3-60° (2θ). Using the Origin software (Version 8.0, Microcal Inc., Northampton, MA, USA) the two-phase method was followed to quantitatively calculate the relative crystallinity (Lopez-Rubio et al., 2008).

Differential scanning calorimetry

Using a differential scanning calorimeter (DSC8000, PerkinElmer Co., Norwalk, CT) to evaluate the thermal properties of the starches, 2 mg starch was weighed in aluminium crucibles. Then redistilled water (6 μl) was added with a pipette and mixed well with a fine needle. The crucibles had a sealing gland and were kept at

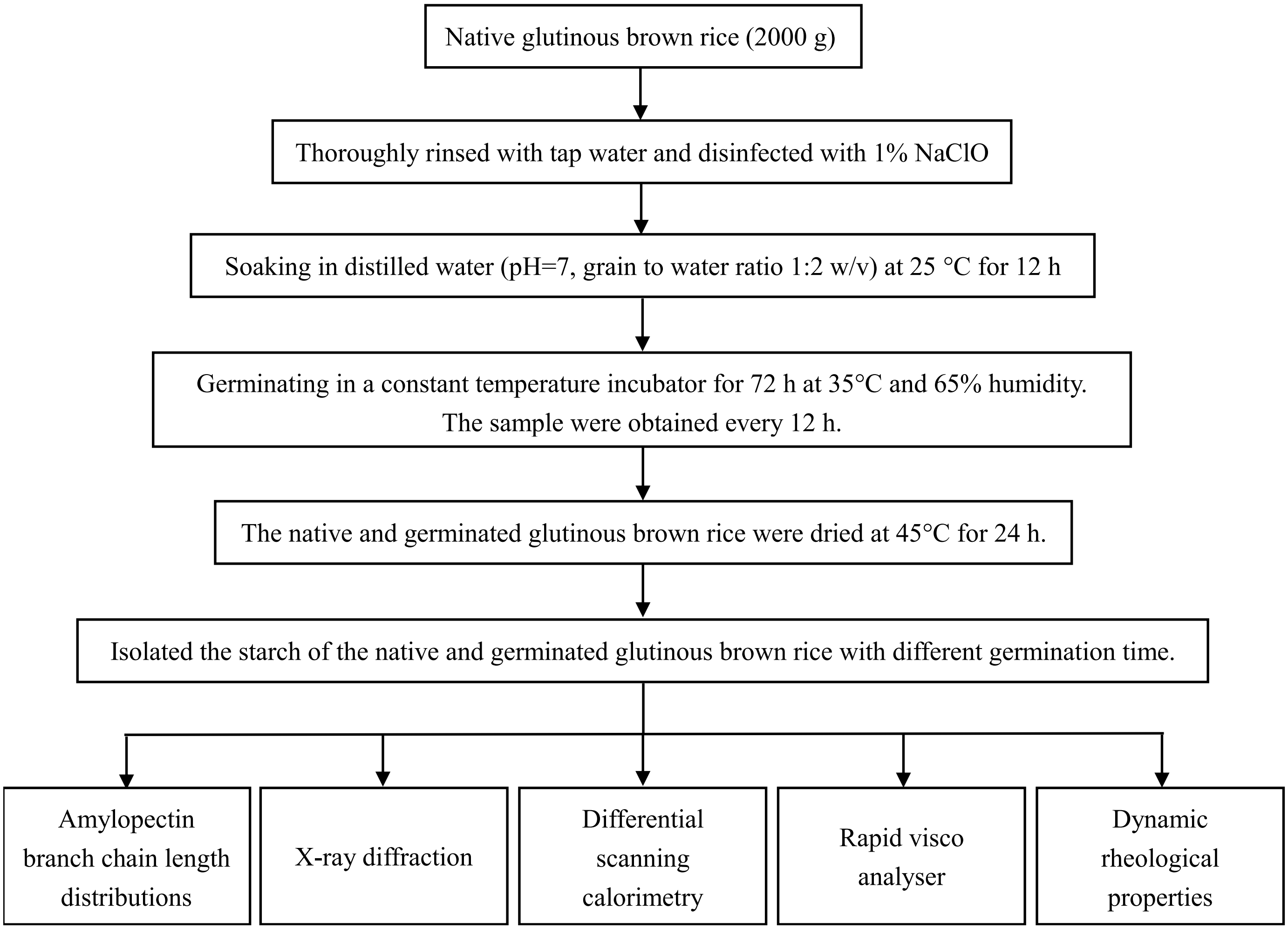

Figure 1. Flow chart.

room temperature to equilibrate moisture for 24 h. The crucibles with a heating rate of 10°C/min were heated from 30 to 130°C. The blank control was used as an empty aluminium crucible. The onset (T_o), peak (T_p), and conclusion (T_c) temperatures, as well as the enthalpy of gelatinization (ΔH) were determined from the data recording software.

Rapid Visco Analyser

A Rapid Visco Analyser (RVA-TecMaster, Warriewood, Australia) was used to analyze the pasting properties of the starches. The starch suspension liquid was prepared (7% w/w, 30 g of total weight), and the temperature program was set as: held at 30°C for 1 min, heated to 95°C at a rate of 6°C/min, held at 95°C for 5 min, cooled to 30°C at 6°C/min, and finally held at 30°C for 2 min.

Dynamic rheological properties

Dynamic rheological properties were evaluated using an HAAKE RheoStress 6000 (Thermo Scientific, USA) with parallel plate system (4 cm plate diameter); the gap size was set at 1 mm, and measured with 0.5% of strain and 1 Hz of frequency. The dried starches were disperse in distilled water (6% dry solids) by heating in a boiling water-bath for 30 min with stirring. The gelatinized sample was immediately transferred on the test board, and preheated to 95°C for the analysis. The free surface of the sample edges was covered with silicone oil to reduce evaporation losses during measurements. The storage (G´) and loss (G") moduli were measured while the paste was cooled to 4°C at a rate of 1 °C /min. The dynamic viscoelastic properties, including elastic modulus (G´), viscous modulus (G"), and complex modulus, G* = (G´ 2 + G"2) 1/2 were recorded as a function of frequency.

Statistical analysis

The SPSS statistical software version 21.0 (SPSS Inc., Chicago, IL, USA) was employed to analyze the significant differences among means ($P < 0.05$) through Duncan's multiple range test.

RESULTS AND DISCUSSION

Structural characterization

Figure 2 shows the normalized HPAEC-PAD chromatogram of the amylopectin branch chain length distribution of the starches isolated from GB0, GB12, GB24, GB36, GB48 and GB72. Researchers divided the normalized amylopectin into four parts: A chains (DP 6–12), B_1 chains (DP 13–24), B_2 chains (DP 25–36), and B_3 chains (DP 25– (Hanashiro et al., 1996). After germination, the proportion of A chains increased significantly; in contrast, the proportion of B_1 chains decreased gradually. The total proportion of chain A and chain B_1 increased. According to the starch cluster model of amylopectin, A and B_1 chains formed double helix structure in starch granules, and was the most part external (Tester et al., 2004). Therefore, part of them are degraded to oligosaccharides to provide energy for the growing germs, which is due to the activation of hydrolases during germination (Mohan et al., 2010). Interestingly, we observed that the total proportion of B_2 and B_3 chains decreased before germination at 36 h; it rose again at 36 h, and then continued to decrease with the extension of germination time. The enzymatic degradation at the beginning of germination may be the cause of this trend. The maximum limit of the amylopectin chain length was approximately 100. Nevertheless, in our HPAEC system, the super longer chains (DP > 78) could not be detected, but they can actually form the whole amylopectin macromolecules by connecting with each other into clusters. So, the super longer chains can degrade during germination and lead to the rise in the proportion of B_2 and B_3 chains of GB36 starch in this study (Hizukuri, 1985).

Crystalline structure

The starches isolated from GB0, GB12, GB24, GB36, GB48, and GB72 all exhibited the typical A-type diffraction pattern with individual peaks at 15° and 23° and unresolved peaks at 17° and 18°. From Figure 3 we could not find any significant changes in the X-ray diffraction pattern of starches after germination. The A-type diffraction pattern reflects a compact packing of amylopectin double helices (Khunae et al., 2007). Compared with the GB0 starch, the relative crystallinity of GB12 starch and GB24 starch had no significant difference.

This shows that the hydrolysis during germination primarily attacked the amorphous area of the starch granules before germination at 24 h. Nevertheless, when germination occurred at 36 h, germination did cause a lower relative crystallinity, and the relative crystallinity was decreased with the germination time. Relative crystallinity is possibly connected with the interaction of double helices (Jane et al.,1999). (Cooke and Gidley, 1992) confirmed that the existence of short amylopectin chains (DP<10) leads to the instability of the double helix. The proportion of DP 10-13 is negatively correlated with crystallinity which is confirmed by Cheetham and Tao (Cheetham and Tao, 1998). Therefore, a high-proportion of A chains in the starch of GB36, GB48 and GB72 may cause the decrease in the relative crystallinity.

Thermal properties

Table 1 presents the thermal properties of the starch samples obtained from GB0, GB12, GB24, GB36, GB48, and GB72. In this study, the gelatinisation temperature of the glutinous brown rice starch decreased slightly following germination. Similarly, You et al. (2016) also declared the gelatinization temperature decreased after germination. The molecular structure of crystalline regions which are related to the amylopectin branch chain length distributions can influence gelatinization temperatures. Thus, low gelatinization temperatures may have resulted from the high proportion of A chain and a less amount of long chain amylopectin (Pinkaew et al., 2017). In addition, the starch exhibited lower gelatinisation enthalpy during the germination. Similarly, Xu et al. (2012) and Li et al. (2017) also found the gelatinization enthalpy of germinated rice starches were lower than the native rice starches. The reduced gelatinization enthalpy after germination can confirm the fracture of the hydrogen bonds linking adjacent double helices (Chung et al., 2008). The damage of double helical order in crystalline and non-crystalline regions can normally be represented by gelatinization enthalpy (Cooke and Gidley, 1992). Gidley and Bulpin (1987) confirmed that the gelatinization enthalpy can also be impacted by the amylopectin branch chain length distributions. The lower proportion of long branch chains constitutes a shorter order of double helical and leads to smaller gelatinization enthalpy(Li et al., 2017)

Pasting properties

The differences of pasting properties between the starch of native and germinated glutinous brown rice are given in Figure 4. The behaviour exhibited was the same as that classically encountered in aqueous starch dispersions. In the present study, gradual decreases were observed in the pasting temperature and viscosities during the germination. Li et al. (2017) suggested that more rigid crystalline structure cannot swell easily. Chung et al. (2011) proposed that keeping the swollen granules in perfect condition needs strong interaction which could not be provided by the high proportion of short chains (DP 6-12) and resulted in lower pasting temperature and pasting viscosities. The higher proportion of A chains (DP 6-12) after germination may result in the decrease in pasting temperature. During germination, the α-1,4-glycosidic linkages of the starch molecules were brokenby activated α-amylase which might explain the high dissolubility and easy saccharification of starch gel, leading to a lower peak viscosity (Zhu et al., 2010).

The breakdown of the glutinous brown rice starches was increased after germination. Keeping the swollen granules in perfect condition needs strong interaction

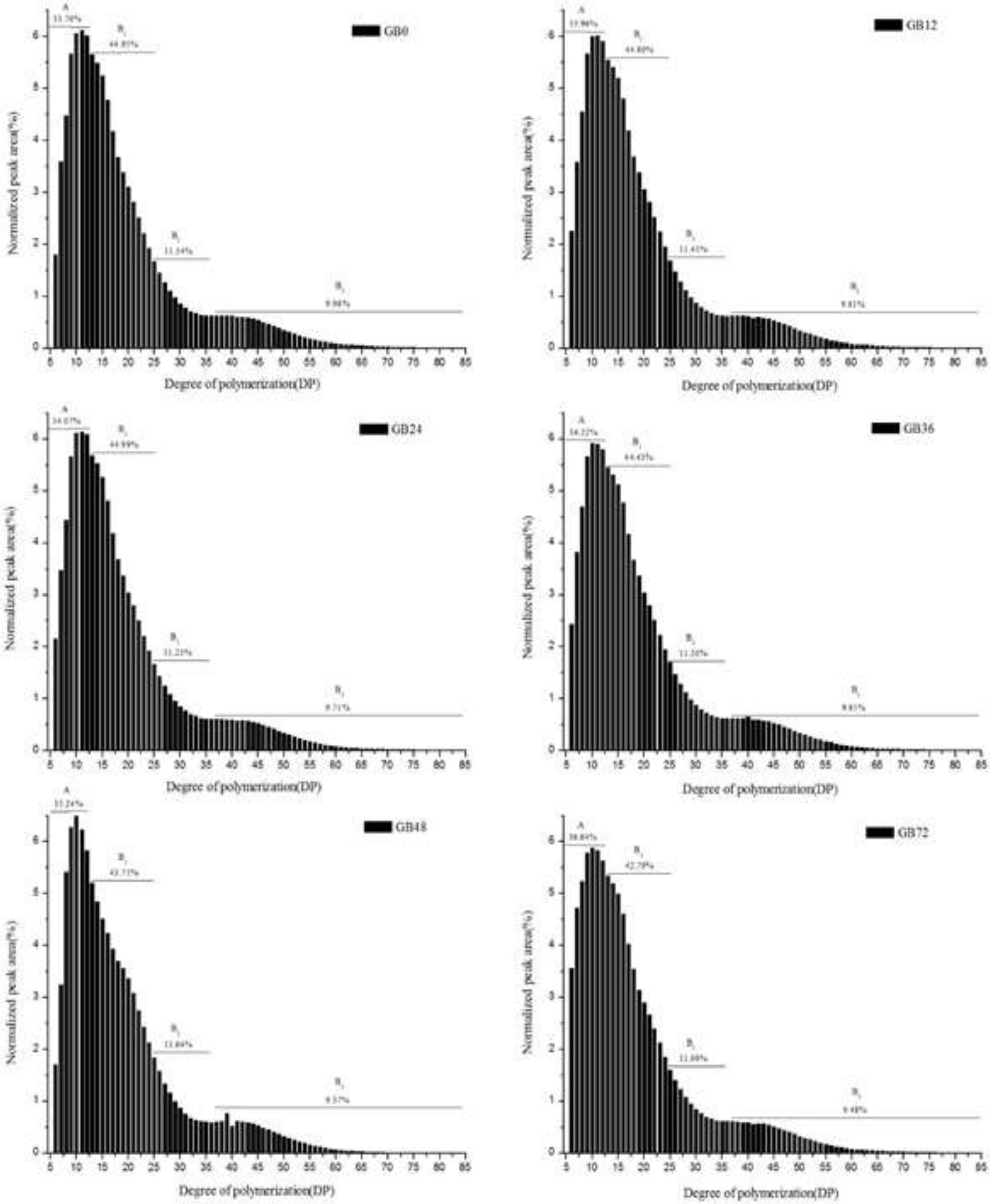

Figure 2. High-performance anion-exchange chromatography normalized chromatogram of native and germinated glutinous brown rice. GB, germinated glutinous brown rice starch; 0, 12, 24, 36, 48, 72, germinated time.

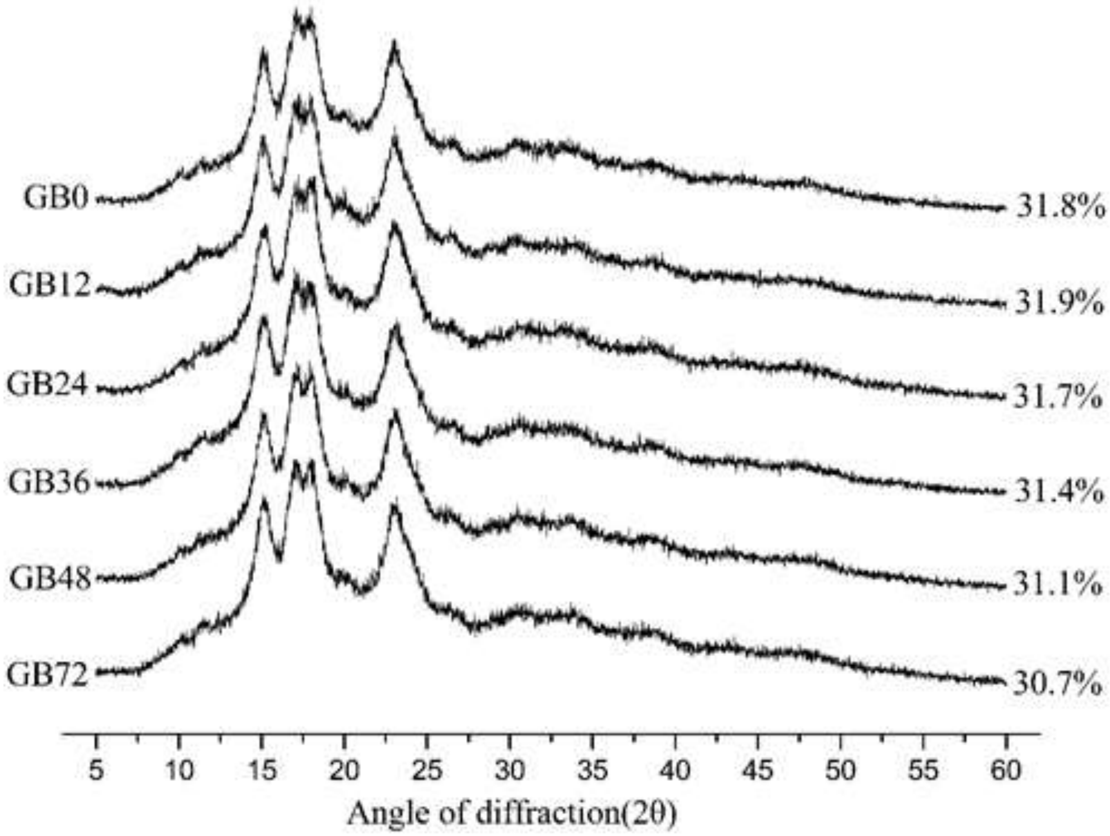

Figure 3. X-ray diffractogram of isolated native and germinated glutinous brown rice. GB, germinated glutinous brown rice starch; 0, 12, 24, 36, 48, 72, germinated time.

Table 1. Thermal properties of native and germinated brown rice [A].

Starch	T_o(°C)	T_p(°C)	T_c(°C)	ΔH (J/g)
GB0	60.20±0.42[a]	65.88±0.06[a]	73.24±0.45[a]	12.72±0.06[a]
GB12	58.38±0.44[b]	66.26±0.52[a]	72.10±0.40[bc]	12.35±0.12[ab]
GB24	58.05±0.19[bc]	65.75±0.25[a]	71.71±0.33[cd]	12.46±0.40[ab]
GB36	57.38±0.42[c]	65.87±0.14[a]	72.28±0.21[bc]	12.29±0.44[ab]
GB48	57.51±0.47[bc]	65.88±0.00[a]	72.83±0.69[abc]	11.87±0.32[b]
GB72	56.28±0.09[d]	65.68±0.18[a]	71.02±0.27[d]	11.95±0.37[ab]

GB, germinated glutinous brown rice starch; 0, 12, 24, 36, 48, 72, germinated time; T_o, onset temperature; T_p, peak temperature; T_c, conclusion temperature; Δ H, enthalpy. [A] Values followed by the different superscripts in the same column are significantly different ($P < 0.05$).

which could not be provided by the short branch chains, so the higher proportion of A chains (DP 6-12) may be due to the larger breakdown (Cheetham and Tao, 1998).

The highest breakdown of GB12 indicates that the shear resistance and thermal stability of the glutinous brown rice starch gel in the present study decreased after germination, and the GB12 starch gel has the weakest thermal stability and shear resistance. The final viscosity and setback decreased after germination, which might be due to the degradation of starch structure during germination in which the gelatinized starch molecules have a low tendency of aggregation during cooling (Li et al., 2017). GB12 also has the highest value of setback during germination; it might indicate that GB12 starch is more difficult to retrogradation.

Dynamic rheological properties

Figure 5 shows the complex modulus of the starch gel of GB0, GB12, GB24, GB36, GB48, and GB72. In dynamic oscillatory measurements, the complex modulus (G*) was redrawn as the logarithm of the temperature. In the first

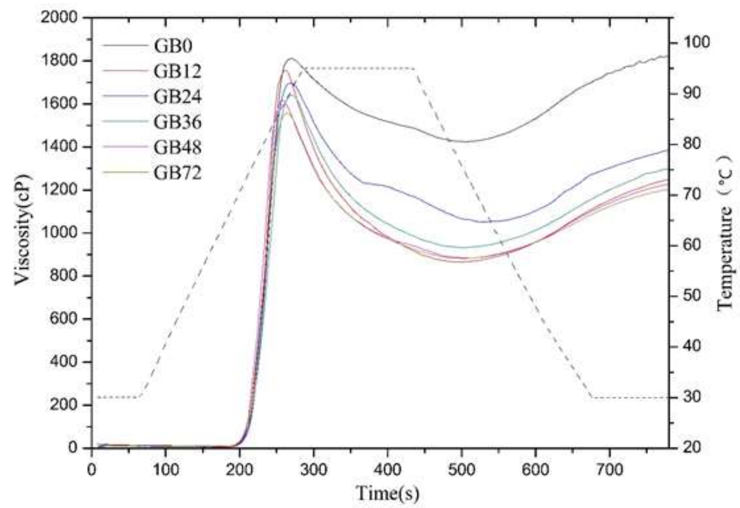

Figure 4. Comparison of the pasting profiles of the native and germinated glutinous brown rice starch. GB, germinated glutinous brown rice starch; 0, 12, 24, 36, 48, 72, germinated time.

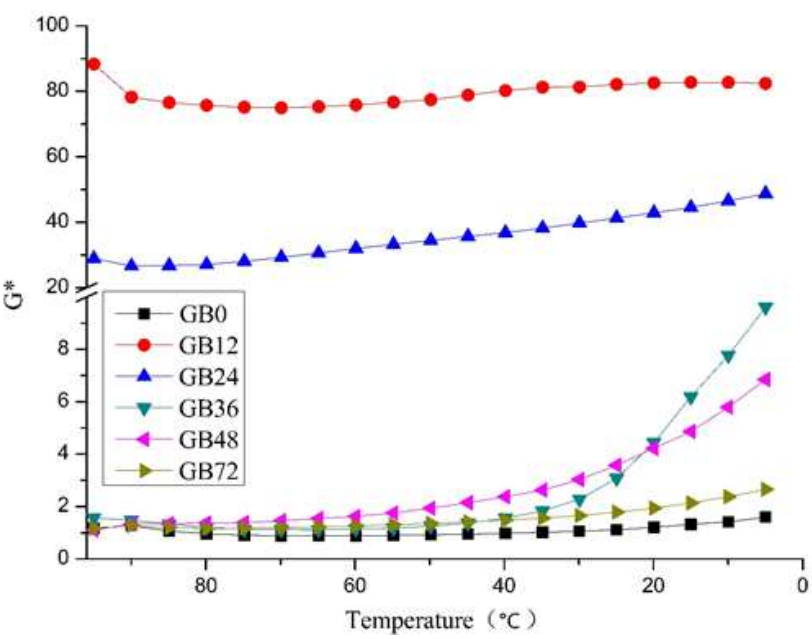

Figure 5. Complex modulus (G*) change versus temperature in log scale during the cooling of the native and germinated glutinous brown rice starch paste (95-4°C). GB, germinated glutinous brown rice starch; 0, 12, 24, 36, 48, 72, germinated time.

stage, the G* increased, and the starch chains in the paste maintained a high fluidity above 50 ℃, so the response to the oscillation strain was not obvious; In the second stage, with the further decrease of temperature, the increase of intermolecular association due to the poor mobility of amylopectin to oscillatory response becomes obvious. Therefore, the higher G* can be the evidence of the overall chain association in the second stage (Chung et al., 2008).

The temperature ($T_{intercept}$) at the intersection point between the first and the second stages of G* increase may express the onset temperature for chain association (Chung et al., 2008). After germination, $T_{intercept}$ increased, and the $T_{intercept}$ of GB36 is the lowest in all the germinated glutinous brown rice starch. This indicates that germination leads to the chain association become harder. Among the second stage in the test, the rising slope of GB36 starch paste was the highest and the GB12 starch paste was the lowest; this indicates that GB36 starch is easy to get into chain association (retrogradation) but GB12 starch is difficult to retrogradation induced by cooling. GB36 has the highest proportion of long B chains, and the long B chains have more possible contact points which are easier to associate between chains(Chung et al., 2008).

Conclusions

This study evaluated the impact of different germination stages on the structural and rheological properties of the glutinous brown rice starch. The proportion of A chains was increased significantly; in contrast, the proportion of B_1 chains decreased gradually. The total proportion of chain A to chain B_1 reduced. Interestingly, we observed that the total proportion of B_2 and B_3 chains decreased before germination at 36 h, and rose again at 36 h, and then continued to decrease with the extension of germination time. The change of chain length distribution has a direct effect on the physicochemical properties of glutinous brown rice starch. Germination leads to a decrease in the degree of the relative crystallinity, gelatinisation temperature, gelatinisation enthalpy and pasting viscosities. In all the germinated glutinous brown rice starches, GB12 starch gel has the weakest thermal stability and its shear resistance is more difficult to retrogradation; the $T_{intercept}$ of GB36 is the lowest and is easier to associate between chains (retrogradation). The effect of germination treatment on the fine structure and *in vitro* digestibility of glutinous brown rice starch has not been studied systematically. Further research is needed to provide theoretical basis for the development of glutinous brown rice starch.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Boluda-Aguilar M, Taboada-Rodríguez A, López-Gómez A, Marín-Iniesta F,Barbosa-Cánovas GV(2013). Quick cooking rice by high hydrostatic pressure processing. LWT-Food Science and Technology 51(1):196-204. https://doi.org/10.1016/j.lwt.2012.09.021

Cheetham NW, Tao L (1998).Variation in crystalline type with amylose content in maize starch granules: an X-ray powder diffraction study. Carbohydrate Polymers 36(4):277-284.

Chen HH, Chang HC, Chen YK, Hung CL, Lin S Y, Chen YS (2016). An improved process for high nutrition of germinated brown rice production: Low-pressure plasma. Food Chemistry 191:120-127. https://doi.org/10.1016/j.foodchem.2015.01.083

Chung HJ, Liu Q, Lee L, Wei D (2011). Relationship between the structure, physicochemical properties and *in vitro* digestibility of rice starches with different amylose contents. Food Hydrocolloids 25(5):968-975. https://doi.org/10.1016/j.foodhyd.2010.09.011

Chung JH, Han JA, Yoo B, Seib PA, Lim ST (2008). Effects of molecular size and chain profile of waxy cereal amylopectins on paste rheology during retrogradation. Carbohydrate Polymers 71(3):365-371. https://doi.org/10.1016/j.carbpol.2007.05.018

Cooke D,Gidley MJ (1992). Loss of crystalline and molecular order during starch gelatinisation: origin of the enthalpic transition. Carbohydrate Research 227:103-112. https://doi.org/10.1016/0008-6215(92)85063-6

Cui L, Pan Z, Yue T, Atungulu GG, Berrios J (2010). Effect of ultrasonic treatment of brown rice at different temperatures on cooking properties and quality. Cereal Chemistry 87(5):403-408. https://doi.org/10.1094/CCHEM-02-10-0034

Das M, Banerjee R, Bal S (2008).Evaluation of physicochemical properties of enzyme treated brown rice (Part B). LWT-Food Science and Technology 41(10):2092-2096. https://doi.org/10.1016/j.lwt.2007.11.018

Gidley MJ, Bulpin PV (1987). Crystallisation of malto-oligosaccharides as models of the crystalline forms of starch: minimum chain-length requirement for the formation of double helices. Carbohydrate Research 161(2):291-300.https://doi.org/10.1016/S0008-6215(00)90086-7

Hanashiro I, Abe JI, Hizukuri S (1996).A periodic distribution of the chain length of amylopectin as revealed by high-performance anion-exchange chromatography. Carbohydrate Research 283:151-159.

Hizukuri S (1985).Relationship between the distribution of the chain length of amylopectin and the crystalline structure of starch granules. Carbohydrate Research 141(2):295-306. https://doi.org/10.1016/S0008-6215(00)90461-0

Jaisut D, Prachayawarakorn S, Varanyanond W, Tungtrakul P, Soponronnarit S.(2009). Accelerated aging of jasmine brown rice by high-temperature fluidization technique. Food Research International 42(5-6):674-681. https://doi.org/10.1016/j.foodres.2009.02.011

Jane JL, Chen YY, Lee LF, McPherson AE, Wong KS, Radosavljevic M, Kasemsuwan T (1999). Effects of amylopectin branch chain length and amylose content on the gelatinization and pasting properties of starch. Cereal Chemistry 76(5):629-637.

Kalita D, Sarma B, Srivastava B (2017). Influence of germination conditions on malting potential of low and normal amylose paddy and changes in enzymatic activity and physico chemical properties. Food Chemistry 220:67-75. https://doi.org/10.1016/j.foodchem.2016.09.193

Khunae P, Tran T, Sirivongpaisal P (2007). Effect of heat-moisture treatment on structural and thermal properties of rice starches differing in amylose content. Starch-Stärke 59(12):593-599. https://doi.org/10.1002/star.200700618

Komatsuzaki N, Tsukahara K, Toyoshima H, Suzuki T, Shimizu N, Kimura T (2007). Effect of soaking and gaseous treatment on GABA content in germinated brown rice. Journal of food engineering 78(2):556-560. https://doi.org/10.1016/j.jfoodeng.2005.10.036

Li C, Oh SG, Lee DH, Baik HW,Chung HJ (2017). Effect of germination on the structures and physicochemical properties of starches from brown rice, oat, sorghum, and millet. International Journal of Biological Macromolecules 105:931-939. https://doi.org/10.1016/j.ijbiomac.2017.07.123

Lim ST, Lee JH, Shin DH,Lim HS(1999). Comparison of protein extraction solutions for rice starch isolation and effects of residual protein content on starch pasting properties. Starch-Stärke 51(4):120-125. https://doi.org/10.1002/(SICI)1521-379X(199904)51:4<120::AID-STAR120>3.0.CO;2-A

Liu H, Corke H, Ramsden L (1999). Functional properties and enzymatic digestibility of cationic and cross-linked cationic ae, wx, and normal maize starch. Journal of Agricultural and Food Chemistry 47(7):2523-2528. https://doi.org/10.1021/jf9811471

Lopez-Rubio A, Flanagan BM, Gilbert EP, Gidley MJ (2008).A novel approach for calculating starch crystallinity and its correlation with double helix content: A combined XRD and NMR study. Biopolymers: Original Research on Biomolecules 89(9):761-768. https://doi.org/10.1002/bip.21005

Mohan BH, Malleshi NG,Koseki T (2010). Physico-chemical characteristics and non-starch polysaccharide contents of Indica and Japonica brown rice and their malts. LWT-Food Science and

Technology 43(5):784-791. https://doi.org/10.1016/j.lwt.2010.01.002

Musa AS, Umar M, Ismail M (2011). Physicochemical properties of germinated brown rice (Oryza sativa L.) starch. African Journal of Biotechnology 10(33):6281-6291.

Noda T, Nishiba Y, Sato T, Suda I (2003). Properties of starches from several low-amylose rice cultivars. Cereal Chemistry 80(2):193-197.

Pinkaew H, Thongngam M, Wang YJ, Naivikul O (2016). Isolated rice starch fine structures and pasting properties changes during pre-germination of three Thai paddy (*Oryza sativa* L.) cultivars. Journal of Cereal Science 70:116-122. https://doi.org/10.1016/j.jcs.2016.05.009

Pinkaew H, Wang YJ, Naivikul O (2017). Impact of pre-germination on amylopectin molecular structures, crystallinity, and thermal properties of pre-germinated brown rice starches. Journal of Cereal Science 73:151-157. https://doi.org/10.1016/j.jcs.2016.12.013

Tester RF, Karkalas J, Qi X (2004).Starch-composition, fine structure and architecture. Journal of cereal science 39(2):151-165. Journal of Cereal Science 39(2)151–165. https://doi.org/10.1016/j.jcs.2003.12.001

Subba Rao MVSST, Muralikrishna G (2002). Evaluation of the antioxidant properties of free and bound phenolic acids from native and malted finger millet (Ragi, Eleusine coracana Indaf-15). Journal of Agricultural and Food Chemistry 50(4):889-892.

Wang H, Hu F, Wang C, Ramaswamy HS, Yu Y, Zhu S, Wu J (2020). Effect of germination and high pressure treatments on brown rice flour rheological, pasting, textural, and structural properties. Journal of Food Processing and Preservation e14474. https://doi.org/10.1111/jfpp.14474

Wu F, Chen H, Yang N, Wang J, Duan X, Jin Z, Xu X (2013).Effect of germination time on physicochemical properties of brown rice flour and starch from different rice cultivars. Journal of Cereal Science 58(2): 263-271. https://doi.org/10.1016/j.jcs.2013.06.008

Xia Q, Wang L, Xu C, Mei J, Li Y (2017). Effects of germination and high hydrostatic pressure processing on mineral elements, amino acids and antioxidants in vitro bioaccessibility, as well as starch digestibility in brown rice (Oryza sativa L.). Food Chemistry 214:533-542.https://doi.org/10.1016/j.foodchem.2016.07.114

Xu F, Zhang G, Tong C, Sun X, Corke H, Sun M, Bao J (2013).Association mapping of starch physicochemical properties with starch biosynthesizing genes in waxy rice (Oryza sativa L.). Journal of Agricultural and Food Chemistry 61(42):10110-10117.https://doi.org/10.1021/jf4029688

Xu J, Zhang H, Guo X, Qian H (2012).The impact of germination on the characteristics of brown rice flour and starch. Journal of the Science of Food and Agriculture 92(2):380-387. https://doi.org/10.1002/jsfa.4588

You SY, Oh SG, Han HM, Jun W, Hong YS, Chung HJ (2016). Impact of germination on the structures and in vitro digestibility of starch from waxy brown rice. International Journal of Biological Macromolecules 82:863-870. https://doi.org/10.1016/j.ijbiomac.2015.11.023

Zhu LJ, Liu QQ, Sang Y, Gu MH, Shi YC (2010). Underlying reasons for waxy rice flours having different pasting properties. Food Chemistry 120(1):94-100. https://doi.org/10.1016/j.foodchem.2009.09.076

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Competition indices and monetary advantage index of intercropping maize (*Zea mays* L.) with legumes under supplementary irrigation in Tselemti District, Northern Ethiopia

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An understanding of competitive and monetary indices such as land equivalent ratio (LER), land equivalent coefficient (LEC), relative crowding coefficient (K) and monetary advantage index (MAI) is critical in recommending cropping systems in a given area. To appreciate this, an experiment was conducted in Tselemti, Tigray region, Northern Ethiopia. Maize (*Zea mays* L.) was intercropped with Soybean and Mung bean in a 50:50 ratio under rainfed conditions and supplemented with irrigation in the 2016/17 season to determine the effect of leguminous competition on maize and the economic viability of the intercropping system over sole cropping. The experiment was laid in a split-plot design in three replications with intercropping taking the main plots and supplementary irrigation to sub-plots. The LER values were generally greater than one which indicated the yield advantages of intercropping over sole cropping. LEC was well above 25% and this means that intercropping was more productive. The highest value of LEC was recorded in wheat-lentil mixtures. The relative crowding coefficient (K) showed that the legumes were more dominant over maize. Although both maize-soybean and maize-mungbean mixtures showed economic advantage, as recorded by positive MAI, maize-soybean intercropping system proved more profitable under rainfed conditions whereas under supplementary irrigation, maize-Mungbean recorded a higher value of MAI. Conclusively, it was demonstrated that maize-soybean combinations were more advantageous in terms of yield and monetary advantage for smallholder farmers in Tselemti area who depend on rainfed farming.

Key words: Competition, mungbean, intercropping, supplementary irrigation, soybean, maize.

INTRODUCTION

Moisture stress negatively affects the physiological and agronomic growth of maize, resulting in significant yield reduction (Balla et al., 2008). However, the use of self-sustaining low input technologies has been suggested as

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Table 1. Chemical and physical characteristics of the soil of experiment.

Sand (%)	Clay (%)	Silt (%)	K ppm	Av.P ppm	Tot. N (%)	C (%)	EC (dSm^{-1})	PH
25	42	33	130.3	1.2	0.1022	1.06	0.32	6.08

EC: Electrical conductivity; CEC: Cation exchange capacity; Tot.N: Total nitrogen; Av.P: Available phosphorus.

a sustainable approach to build soil productivity of such areas, with minimum use of external inputs. Supplementary irrigation has also been reported to increase yields in drylands by more than 50% (Bello, 2008). Cereal-legume intercropping is among such practices recommended for soil restoration in Ethiopia (Coxhead and Oygard, 2008).

Intercropping is a multiple cropping system that combines the planting of two or more crops species simultaneously in the same field during a growing season (Mousavi and Eskandari, 2011). It has the capacity to fulfill several agro ecological goals such as enhancing the natural nutrient regulation (Chapagain, 2014), efficient use of resources, and weed supprFession (Chapagain, 2014; Ghanbari et al., 2010) among others. In Ethiopia, intercropping forms part of the smallholder farming systems where maize (*Zea mays* L.) and sorghum (*s. bicolor* L.) dominate as main crops (Tarekegn and Zelalem, 2014).

Despite its numerous benefits, the practice is being abandoned for sole cropping since the current extension services and technologies in the country are promoting sole cropping. Hence in many parts of Ethiopia, farmers mostly harvest only once in a year on sole crop basis even in areas that receive sufficient rainfall (Yayeh et al., 2014b). Nevertheless, this does not provide sufficient food supply for the households and does not make efficient use of the limited resources such as rainfall and land.

However, management practices that emphasize the integration of maize with leguminous species could optimize the use of environmental resources, increase production where land area expansion is not possible and also enhances rich and diversified diet options. Yet, these benefits and interaction were not properly studied in the study area. Studies in other areas have shown that indices such as land equivalent ratio (LER) are useful to substantiate the resource utilization efficiency of intercropping system (Willey and Osiru, 1972), land equivalent coefficient (LEC) to measure the strength of the relationship (Adetiloye et al., 1983), relative crowding coefficient (K) to measure the relative species dominance of multiple cropping (De Wit, 1960), and monetary advantage index (MAI) to evaluate the economic benefits of intercropping over sole cropping (Willey, 1979).

Therefore, such indices should be taken into account in recommending cropping systems for a given area. Thus, the objectives of this paper were;

(1) To determine the effect of competition among the two different leguminous species (soybean *Glycine max* (L.) Me rril) and Mungbean (*Vigna radiata*) in maize intercropping;

(2) To study the economic viability of intercropping maize with soybean and mungbean compared to its sole cropping under supplementary irrigation (SI).

MATERIALS AND METHODS

Description of the study area

The field study was conducted at Tselemti wereda, which is found in North Western Tigray administration zone during the 2016/2017main cropping season (about 13^0 59'N, 38^0 14'E at 1323 meters above sea level). It is located in the arid agro-ecology with a unimodal type of rainfall received around June. Agriculture is the main livelihood of the community in the study area. Known for their mixed farming system, the rural people depend on crop and livestock production in addition to agro forestry practices for their living. People are also engaged in traditional gold mining as a main off- farm income. Soil in the area is classified as clay (Table 1 and Figure 1).

Experimental design and treatments

Maize variety, obtained from Melkassa Agricultural research center was intercropped with two legume species; Soybean and Mung bean in the ratio of 1:1 under rainfed and supplementary irrigation in a split-plot design with three replications. The main plot constituted the two intercropping combinations while supplementary irrigation was applied to the sub-plots. Pure stands of maize, soybean and mungbean as well as the solitary ratios of Maize-legume intercropping were planted. Sole maize was planted at a seeding rate of 125 kg ha^{-1}, sole soybean and mungbean at seeding rates of 65 and 30 kg ha^{-1} respectively. Whereas for the intercropped treatment of maize, half of the recommended seeding rate was applied. Maize was drilled 75 cm between rows, while Soybean was drilled at a spacing of 60 cm and Mung bean was planted at a spacing of 10 x 40 cm. The space between the rows of maize and any legume rows was 20 cm. A basal fertilizer application of Di ammonium phosphate (DAP) (18% N, 46%P) at a rate of 100 $kgha^{-1}$ and 50 $kgha^{-1}$ urea (46% N) at planting, while the second half of urea was top-dressed at tillering stage. A 135 mm supplementary irrigation was applied to the irrigated sub-plots at booting stage to replenish soil moisture during the dry spells.

Competition indices and monetary advantage index

Land equivalent ratio (LER)

LER was used as the first criteria to demonstrate the advantages mixed cropping over the other among the different species (Willey,

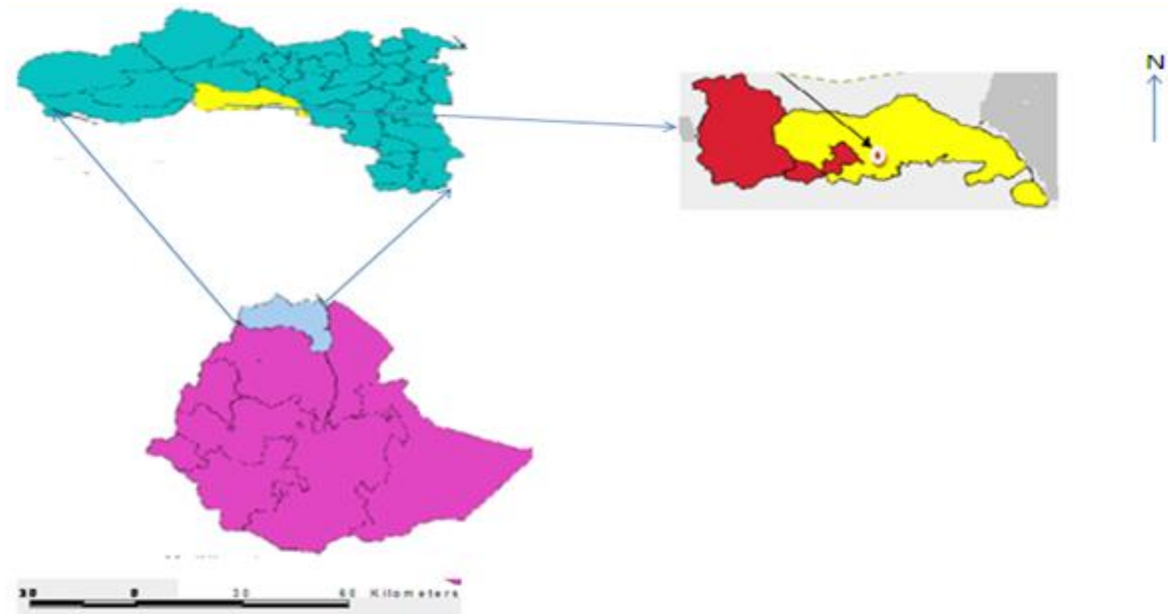

Figure 1. Location of the study area.

1979). It shows the effectiveness of intercropping in resource utilization in the environment in comparison with monocropping (Mead and Willey, 1980). In other words, LER can be used to indicate complementarities among species in the intercrop (Yayeh et al., 2014b). A unitary value of LER is the reference value. LER value greater than one indicates that intercropping is advantageous over sole cropping in terms of growth and yield of both species. A value of LER less than one, indicates the negative effect of the interaction on the species in the mixture (Ofori and Stern, 1987; Yayeh et al., 2014b). Therefore, LER was calculated according to Willey and Osiru (1972), as;

LER = LER Wheat (A) + LER Legume (B);

where, LER wheat $=(\frac{Y_A I}{Y_A S})$and LER Legume = $(\frac{Y_B I}{Y_B S})$

Where:

Y_AI and Y_BI are yields of wheat and legume in the intercrop respectively while Y_AS and Y_BS are the sole crop yields of wheat and the legumes respectively.

Land equivalent coefficient (LEC)

The strength of the intercropping interaction was determined using land equivalent coefficient (LEC), also referred to as the productivity index (PC). LEC was used because it is a more superior index in evaluating crop mixture performance in terms of mixture productivity (Adetiloye et al., 1983). Thus, was calculated as;

LEC = L*a* x L*b*

Where:

L*a* = LER of main crop and L*b*= LER of intercrop

coefficient (PC) is 25%, that is, a yield advantage is obtained if LEC value exceeds 0.25.

Crowding coefficient (K)

Crowding effect is also one of the indices used in computing the competition effect of intercropping. It gives a measure of the relative dominance of one species over the other in multiple cropping (Banik et al., 2006). Each of the species within an intercropping has its own relative crowding coefficient and the one with higher values are said to be more dominant (De Wit, 1960). It was calculated according to the formula below;

$$Kab = \frac{\text{Yab}}{\text{Yaa} - \text{Yab}} \quad \text{and} \quad Kba = \frac{\text{Yba}}{\text{Ybb} - \text{Yba}}$$

Where:

Kab and Kba are the relative crowding coefficient of wheat in legume and legume in maize respectively; Yaa and Ybb are yields of maize and legumes in monoculture; Yab is the yield of maize in poly culture with a legume and Yba to denote the yield of the legume in the intercrop. When the value of K is greater than 1, there is a yield advantage, when K is equal to 1, it indicates no yield advantage and K values less than one show a yield disadvantage of intercropping.

Monetary advantage index (MAI)

The economic feasibility of intercropping over sole cropping was calculated using the monetary advantage index (MAI). MAI is an important index in determining economic viability of intercropping. It was calculated according to Willey (1979) as;

For a dual-crop mixture, the minimum expected productivity

$$\text{MAI} = \frac{(\text{value of combined intercrops})\text{x}\ (\text{LER} - 1)}{LER}$$

Table 2. Land equivalent ratio (LER) and Land equivalent coefficient (LEC) of maize-legume intercropping at Tselemti, Ethiopia in 2016/2017.

Rainfed					Supplementary irrigation			
	LER				LER			
Treatment	Maize	Legume	Total	LEC	Maize	Legume	Total	LEC
Maize + Soybean	1.06	0.77	1.83	0.82	1.47	0.91	2.38	1.34
Maize +Mungbean	0.78	0.46	1.24	0.36	1.38	0.52	1.9	0.72

The higher MAI value will indicate more profitable cropping system over the other (Muhammad et al., 2008). The value of the component crops were computed basing on the average market price in Tselemti area in Ethiopian Birr (ETB) after harvest time.

Data analysis

Data were statistically explored using the descriptive analysis of variance (ANOVA). Gen Stat version 14 was used for each of the indices (Payne, 2014) according to standard analysis of variance procedures (Gomez and Gomez, 1984), and least significant difference (LSD) test at 5% probability level using Duncan's multiple range test was used to compare the treatment means.

RESULTS AND DISCUSSION

Competitive indices

Land equivalent ratio (LER) and land equivalent coefficient (LEC)

LER is an effective and widely used index for comparing intercropping systems due to different species growing on the same piece of land (Beets, 1982; Yayeh et al., 2014b). Intercropping maize with Soybean and Mung bean under rainfed and supplementary irrigation significantly ($p < 0.05$) affected LER.

In general, the partial LER for maize was lower in maize-legume mixtures than in sole wheat both in rainfed and with supplementary irrigation. Higher partial LERs (0.77 and 0.91) were registered under maize-soybean mixtures under rainfed and supplementary irrigation respectively (Table 2). Intercropping Maize with Soybean gave higher values of total LER (1.83 and 2.38) respectively compared to maize-mungbean mixtures under rainfed and supplementary irrigation (Table 2). This indicates that 83% (0.83 ha) and 138% (1.38 ha) more land area in sole cropping system would produce the same yield as in the intercropping system of maize and soybean under rainfed and supplementary irrigation respectively.

Nevertheless, maize-mungbean also gave LER values greater than one under both water regimes, also indicating a yield advantage over sole cropping (Table 2). This also demonstrates that intercropping systems were more effective in utilization of environmental resources for growth and yield formation over sole cropping. Similar results were also reported by Yayeh et al. (2014a) who reported values of LER well above one in wheat-lupine and barley-lupine intercropping.

Likewise, Caballero et al. (1995) reported intercropping vetch with oat to be advantageous in terms of yield over sole cropping. According to Willey (1979), intercropping systems with constantly higher LERs well-above one are considered more resource-use efficient than mono crops. Muhammad et al. (2008) and Yadav and Yadav (2001) also reported yield advantage in crop mixtures than equivalent sole crops on the same land area. However, this varies with the species combination and seeding ratio.

High population of cereals have been reported to negatively affect the overall yield, hence resulting in LER values less than one. For instance, B. Yayeh et al. (2014a) reported LER values less than one in lupine-barley and lupine wheat intercropping in the ratios of 75:100 and 50:100 respectively. This was probably due to higher competitive ability of the cereals at higher populations. Matching duration of maturity between the component crops was also reported to reduce the value of LER to less than one in lupine-finger millet intercropping since they were assumed to have critical resource demands at the same time period (Yayeh et al., 2014a) (Table 2).

The study showed that the LEC of maize was significantly affected ($p < 0.005$) by intercropping with soybean and Mung bean, and LEC was generally greater than 25% in all the treatments (Table 2). Maize-Soybean intercropping demonstrated more productivity as was demonstrated by higher LEC values of 0.82 and 1.34 in rainfed and irrigated conditions respectively as compared to Maize-mungbean mixture (Table 2). Expectedly, supplementary irrigation recorded higher LEC than rainfed conditions as shown in the Table 2. The results aforementioned demonstrated that intercropping had yield advantage over sole cropping and maize-soybean combination was to be more productive both with rainfed and supplementary irrigation. Egbe (2010) also reported LEC values above 25% in maize intercropping systems.

Relative crowding coefficient (K)

Relative crowding effect was another coefficient used in the study and it is the relative dominance of one species over the other (Banik et al., 2006). The relative crowding

Table 3. The relative crowding coefficient (K) for mixtures of maize and legumes under rain fed and supplementary irrigation in Tselemti, Ethiopia in 2016/2017.

Treatment	Relative competition coefficient (K)					
	Maize + Soybean			Maize + Mungbean		
	Kw	Kl	K	Kw	Kd	K
Rainfed	-16.67	3.33	-55.56	3.55	0.85	3.02
SI	-3.12	10	-31.21	-3.63	1.08	-3.93

Kw: coefficient of wheat; Kl: coefficient of lentil; Kd: coefficient of dekoko; K: product of coefficient.

Table 4. The MAI for maize-legume intercropping in Tselemti, Ethiopia.

Treatment	Monetary advantage index (MAI) (ETBr)	
	Rainfed	Supplementary Irrigation
Maize + Soybean	7.937.2	20.642
Maize + Mungbean	4.983.9	22.500

coefficient (K) was significantly affected ($p < 0.05$) by intercropping wheat with the legumes. The partial K values indicated that the legumes were more species to maize in the crop mixtures (Table 3).

Soybean exhibited greater dominance in both rainfed and supplementary irrigation conditions. The study also showed that the partial K for maize was greater than one (3.55) in maize-mungbean intercropping under rainfed conditions. However, it was less than one in the soybean intercropping scenario (Table 3). Under supplementary irrigation, the partial K for maize was less than one in both maize-soybean and maize-mungbean intercropping. Overall, the product of K was less than one in both intercropping scenarios under the two water regimes, except for the case of maize-mungbean intercropping under rainfed conditions.

It can be inferred that intercropped legumes utilized resources more competitively than maize hence were more dominant. Additionally, partial K values for soybean were higher than that of mungbean which is an indication that soybean was more competitive than mungbean in the maize-legume mixtures. This finding was in line with the findings of Yilmaz et al. (2008) who reported that legumes become more competitive than the cereals when planted in equal proportions. However, it contradicts with the findings of Banik et al. (2006) who reported more competitiveness of maize in maize-chickpea intercropping, which was attributed to better resource utilization by the cereal than the component legume. The negative values indicated yield disadvantages of maize intercropping with soybean and mungbean.

Similar findings were reported by Dhima et al. (2007) and Tahir et al. (2003) who reported yield disadvantages in wheat-vetch and wheat-canola intercropping systems respectively over the respective monocultures. This index however did not provide a more realistic comparison of yield advantage and was relatively indifferent to LER and LEC (Table 3).

Economic advantage of intercropping

Monetary advantage index (MAI)

Most intercropping indices mainly give the agronomic and yield advantages of intercropping, and do not take into account the economic and absolute yield comparisons (Tamado and Mulatu, 2000; Yayeh et al., 2014b). Nevertheless it is necessary to perform some monetary evaluations to satisfactorily compare the value of the yield advantage (Willey, 1979).

The study demonstrated that intercropping wheat with legumes significantly affected the MAI ($p < 0.05$). It showed that MAI was positive in all the intercropping systems and higher above one (Table 4). This indicates that the intercropping systems were more economically feasible weighed compare to sole cropping. This conforms to similar results by Dutta et al. (1994) on maize-rapeseed combinations.

MAI was higher in maize-soybean in the absence of supplementary irrigation (ETBr 7,937.2). However, with application of supplementary irrigation, Maize – mungbean intercropping had higher values of MAI (ETBr 22,500) (Table 4). These results imply that it was more economically viable to intercrop maize with lentil under rainfed conditions in the study area, whereas Maize-mungbean intercrop demonstrated economic advantage under supplementary irrigation. This signifies unsuitability of mungbean in maize intercropping under rainfed conditions and entails that maize-soybean intercropping systems is more suitable for the rainfed farming systems of the study area. These results followed a similar trend as the LER and LEC competitive indices (Table 2). It was reported by Dhima et al. (2007) that when LER and LEC values are higher, there is also economic advantage in terms of MAI. Intercropping lupine-wheat and lupine-finger millet also gave more economic returns compared to sole cropping (Yayeh et al., 2014a).

CONCLUSION AND RECOMMENDATIONS

LER was greater in both maize-soybean and maize-mungbean intercropping and as well, the LEC was greater than 25%. MAI was also positive showing that intercropping was more efficient in terms of resource utilization in the environment than sole cropping. Moreso, LER demonstrated that 24 and 83% more land in maize-mungbean and maize-soybean respectively would be required in sole cropping to produce the same yields as in intercropping under rainfed conditions. Therefore, intercropping would serve as a more sustainable way of improving soil productivity among the low-input farmers in Tselemti area and similar agro ecologies. It also suggests maize-soybean as the most economical combination for maize intercropping in the area. Besides, these leguminous are new crop to the study area but in short time accepted they use those for local consumption and market. Therefore, introducing intercropping to the areas gives more advantages to the farmers. However, this study considered only a single ratio of combination of maize and the legumes, and in only one location. We recommend that a similar study should be conducted using different seeding ratios and with different intercropping patterns in different agro-ecologies to come with conclusive recommendations. In addition, a cost-benefit analysis of the different intercropping combinations and patterns would lead to the most economically feasible combination and agronomic management to be recommended for the smallholder farmers in the area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Adetiloye PO, Ezedinma FOC, Okigbo BN (1983). A land equivalent coefficient (LEC) concept for the evaluation of competitive and productive interactions in simple to complex crop mixtures. Ecological Modelling 19(1):27-39.

Balla A, Yeun Ju Kim, Peter V, Zsofia S, Zachary K, Kevan M, Shokat, Tamas B (2008). Maintenance of hormone-sensitive phosphoinositide pools in the plasma membrane requires phosphatidylinositol 4-kinase IIIα. Molecular biology of the cell 19(2):711-721.

Banik P, Midya A, Sarkar BK, Ghose SS (2006). Wheat and chickpea intercropping systems in an additive series experiment: advantages and weed smothering. European Journal of Agronomy 24(4):325-332.

Beets WC (1982). Multiple cropping and tropical farming systems (Gower Publishing Co.).

Bello WB (2008). The Effect of Rain-Fed and Supplementary Irrigation on the Yield and Yield Components of Maize in Mekelle, Ethiopia.Ethiopian Journal of Environmental Studies and Management 1(2):1-7.

Caballero R, Goicoechea EL, Hernaiz PJ (1995). Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of vetch. Field Crops Research 41(2):135-140

Chapagain T (2014). Intercropping wheat and barley with nitrogen fixing legume species in low input organic systems, Electronic Theses and Dissertations (ETDs) 2008+.

Coxhead I, Oygard R (2008). Land degradation, Submitted for Copenhagen consensus.

De Wit CT (1960). On competition. Verslagen van landbouwkundige onderzoekingen. No. 66.8', Institute for biological and chemical research on field crops and herbage. Wageningen.

Dhima KV, Lithourgidis AS, Vasilakoglou IB, Dordas CA (2007).Competition indices of common vetch and cereal intercrops in two seeding ratio. Field Crops Research 100(3):249-256.

Dutta H, Baroova SR, Rakhowa DJ (1994). Feasibility and economic profitability of wheat (*Triticum aestivum*)-based intercropping systems under rainfed conditions. Indian Journal of Agronomy 39(3):448-450.

Egbe OM (2010). Effects of plant density of intercropped soybean with tall sorghum on competitive ability of soybean and economic yield at Otobi, Benue State, Nigeria. Journal of Cereals and Oilseeds 1(1):1-10.

Ghanbari A, Dahmardeh M, Ali BS, Ramroudi M (2010). Effect of maize (*Zea mays* L.)-cowpea (*Vigna unguiculata* L.) intercropping on light distribution, soil temperature and soil moisture in arid environment. Journal of Food Agriculture and Environment 8(1):102-108.

Gomez KA, Gomez AA (1984). Statistical procedures for agricultural research (John Wiley & Sons).

Mead R, Willey RW (1980). The concept of a land equivalent ratio'and advantages in yields from intercropping. Experimental Agriculture 16(3):217-228.

Mousavi SR, Eskandari H (2011). A general overview on intercropping and its advantages in sustainable agriculture. Journal of Applied Environmental and Biological Sciences 1(11):482-486.

Muhammad A, Umer EM, Karim A (2008). Yield and competition indices of intercropping cotton (*Gossypium hirsutum* L.) using different planting patterns. *Tarim Bilimleri Dergisi* 14(4):326-333..

Ofori F, Stern WR (1987). Cereal–legume intercropping systems. Tarim Bilimleri Dergisi 14(4):326-333.

Payne M (2014). Modern social work theory (Palgrave Macmillan).

Tahir M, Malik MA, Tanveer A, Ahmad R (2003). Competition functions of different canola-based intercropping systems. Asian Journal of Plant Sciences 2(1):9-11.

Tamado T, Mulatu E (2000). Evaluation of sorghum, maize and common bean cropping systems in East Hararghe, Eastern Ethiopia. Ethiopian Journal of Agricultural Sciences 17(2):33-45.

Tarekegn A, Zelalem T (2014). Evaluation of the performance of herbaceous forage legumes under sown with maize under irrigation condition of Megech North Gondar, Ethiopia. 26, 06.

Willey RW (1979). Intercropping Its Importance And Research Needs Part 1. Competition And Yield Advantages 32:1-10

Willey RW, Osiru DSO (1972). Studies on mixtures of maize and beans (Phaseolus vulgaris) with particular reference to plant population. The Journal of Agricultural Science 79(3): 517-529.

Yadav RS, Yadav OP (2001). The performance of cultivars of pearl millet and cluster bean under sole cropping and intercropping systems in arid zone conditions in India. Experimental Agriculture. 37(2):231-40.

Yayeh B, Fetien A, Tadesse D (2014a). Effect of lupine (*Lupinus* spp.) intercropping and seed proportion on the yield and yield component of small cereals in North western Ethiopia. African Journal of Agricultural Research 9(30):2287-2297.

Yayeh BB, Abay F, Dessalegn T (2014b). Effect of lupine (*Lupinus* spp.) intercropping and seed proportion on the yield and yield component of small cereals in North western Ethiopia. African Journal of Agricultural Research 9(30):2287-2297.

Yilmaz Ş, Atak M, Erayman M (2008). Identification of advantages of maize-legume intercropping over solitary cropping through competition indices in the East Mediterranean Region. Turkish Journal of Agriculture and Forestry 32(2):111-119.

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