HORTICULTURAL TRAITS AND SEED STORAGE QUALITY OF CHINA ASTER AS INFLUENCED BY SEED SOURCES, STORAGE MATERIALS AND GROWING SEASONS

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Department of Horticulture and Agricultural Biotechnology

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The thesis attached hereto, entitled " **Horticultural Traits and Seed Storage Quality of China aster as Influenced by Seed Sources, Storage Materials and Growing Seasons**" was prepared under the direction of the chairperson of the candidate's Supervisory Committee and has been approved by all members of that committee and board of examiners as a partial fulfillment of the requirements for the degree of **MASTER OF AGRICULTURAL SCIENCE (HORTICULTURE AND AGRICULTURAL BIOTECHNOLOGY).**

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DECLARATION OF ORIGINALITY

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

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Date -------------------------

DEDICATED TO MY BELOVED PARENTS,

U MYINT TUN AND DAW SOE MI MI THU

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ABSTRACT

Three sets of experiments were involved in this study. They were carried out at the Department of Horticulture and Agricultural Biotechnology, Yezin Agricultural University from October, 2012 to August, 2014. **In experiment I**, China aster seeds collected from four locations: Yangon (YGN), Taungoo (TGO), Pyinmana (PMA), and Pyin-Oo-Lwin (POL), were employed to evaluate horticultural traits and phylogenic relationships among *Callistephus* accessions by using Power Marker version 3.2. *Callistephus* accessions clustered into three main groups in UPGMA (unweighted pair-group method) dendrogram. Group I and II included Pyin-Oo-Lwin seed source, and group III contained Yangon, Taungoo, Pyinmana seed sources. **In experiment II**, seeds from Group III, the same morphological characteristics in the UPGMA dendrogram, were selected to evaluate their horticultural traits in two different growing seasons. Floral bud initiation (41.87), first flower opening (63.37) and 50 percent flowering (65.50) were later, but number of leaves (19.75) and plant height (51.00 cm) were higher in winter season than in rainy season. Rainy season produced more number of flowers (14.28) but with smaller flower diameter (5.39 cm) than winter season. **In experiment III**, China aster seeds were stored in five storage materials (paper, aluminum foil, clear polythene, brown bottle and cloth) to determine seed storage quality. There was a decrease in seed storage quality (germination percentage, germination index and seedling vigour index) as increase in storage duration. After six months of storage, seed stored in Aluminum foil showed the highest germination percentage (85.17%), maximum germination index (31.29) and greatest seedling vigour index (350.33) while those stored in cloth bag showed the lowest value in germination percentage (60.67%) and seedling vigour index (260.50). Aluminum foil was the best storage material for China aster seed in this study.

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1. INTRODUCTION

China aster (*Callistephus chinensis* L.) belongs to 'Asteraceae' family and is native to China (Navalinskien et al., 2005). It is one of the most important annual flower crops grown in most parts of the world. Among the annual flowers, it ranks third after Chrysanthemum and Marigold (Sheela, 2008). The centre of flower head (capitulum) consists of yellow disk florets, sometimes it is purple or rose-purple. In most cultivars, the centre of the flowerhead is surrounded by one or two rows of petal-like ray florets that are blue, purple, violet, pink, or white. In Myanmar, China aster cultivars are available with different colour ranges like dark pink, light pink, red, white and purple in market. China aster with long stem, many branches and large flower size are more marketable than long stem with small flower size. It is mainly used as cut flowers in special ceremonies such as wedding and religious ceremonies (offerings to Buddha) etc.

China aster can be grown successfully under different agro-climatic conditions. Increased flower quantity and quality is the main target in commercial flower production. Although there are sufficient number of cultivars under cultivation but their performances are region specific and vary from place to place. The quality of flowers is primarily a varietal trait; however they can be influenced by nutritional and climatic conditions that prevail during the growing period (Boodley, 1975). Climatic factors like photoperiod, temperature, relative humidity and also soil moisture influence both vegetative and reproductive phases of the plant, ultimately leading to the variation in the performance of genotypes. Flowering was strongly influenced by environment (daylength and temperature) (Luckana, 1992). China asters are normally classified as long day plants (Poesch and Laurie, 1935). However, research indicates that asters will flower under short day conditions but will produce small, stunted plants of little commercial value (Lin and Watson, 1950). Two stages were observed in flowering of aster. A period of long day (at least 16 h of light) is required for the induction of stem elongation, and then followed by a period of short day (10 h of light or less) for the flower induction (Schwabe, 1985). Flowerhead longevity was shorter under higher temperature. Flower head size is smaller during summer than the cooler weather. The increased duration of flower development at lower temperature increases the market value of the flowers (Oren et al., 2000). Hence, plants have to be exposed to proper climatic factors in order to get good quality flower and high flower yields. Hence, there is a need to standardize the production technology involving systematic investigation to evaluate suitable varieties. However, there is limited information on horticultural traits of China aster in response to different growing seasons in Myanmar.

Since China aster is commonly propagated by seeds, the seeds are basic materials for plant propagation from one generation to another. The seed quality is mainly influenced by the mother plant nutrition, management of pest and diseases, irrigation and harvesting of capitula at the right stage. Harvesting of seed crop at the optimum stage of physiological maturity helps to obtain the seeds with maximum germination and vigour (Jerlin et al., 2001; Perry, 1982).

The successful seed production also involves seed storage as a proverb “seed saved is seed produced” is rightly applicable in modern agriculture as seed viability decrease due to the certain internal and external factors. Storage potential of seed is basically under genetic control and it differs with species and cultivars (Gnyandev, 2006). Storage conditions such as moisture content, relative humidity, temperature, storage containers etc. influence the seed storage potential. Literatures indicated that seeds stored in sealed moisture impervious containers can store for longer period compared to those stored in moisture pervious containers as they act as effective barriers against seed moisture fluctuation (Thomson, 1979; Lauridsen et al., 1992). High quality seed enables farmers to attain crops, which have the most economical planting rate, a higher percentage of seed emerging in the field, a minimum of replanting, a vigorous seedling establishment, a more uniform plant stand, faster growth rate, and greater resistance to stress and diseases and uniformity in ripening (Hamdollah, 2012). In Myanmar, farmers use wooden boxes, glass bottles and paper to store seeds of China aster. Currently, there is limited information about the horticultural traits of China aster and their responses to different growing seasons. Moreover, it is important to find out the most suitable seed storage material that can sustain high seed viability would also be needed. Based on the above information, the experiments were conducted by the following objectives.

1. To determine the phylogenic relationship of China aster.
2. To evaluate the horticultural traits of China aster at different seasons.
3. To find out the most suitable seed storage material for maintaining good seed quality of China aster.

2. LITERATURE REVIEW

2.1 China aster (*Callistephus chinensis* L.)

China aster (*Callistephus chinensis* L.) is a half hardy annual and commercial flower crop belonging to the family Asteraceae. It is an important annual crop of our country and grown throughout the world. The crop is native to China and spreads to European countries and other tropical countries during 1731 AD (Desai, 1967). The genus *Callistephus* is derived from two Greek words *Kalistos* meaning 'most beautiful' and *Stephus*, 'a crown' referring to the flower head.

Fleming (1937) estimated approximately 10 per cent natural crossing in China aster. Strube (1965) described floral biology of China aster. According to him, its flower head consists of both pistillate ray florets and perfect disc florets. The proportion of ray florets and disc florets is a measure of doubleness of the flower. As a rule, the stamens and pistils do not mature simultaneously in the individual flower. The stigma of the individual flower unfolds after the pollen is discharged from the flower. However, sufficient pollen remains in the capitulum. The China aster was therefore, in geitenogamous condition (the pollination is accomplished by rain drops). In some varieties, they mature together leading to self fertilization. North (1979) and Watts (1980) grouped China aster under self-pollinated crops.

China aster is a free blooming annual grown all over the world for its cut and loose flowers. The bloom period of the flower varies from mid-summer to winter season and originally China aster blossoms in the month of August for world species. The species consists of diverse forms, types and wide spectrum of colour ranges. Erect growth and spreading growth habits are common in China aster. In erect growing types, many cultivars are available with colour ranges like blue, pink, white, purple and red. Whereas, in spreading growth habit, the colours available are blue, pink, white and purple. In case of powder puff types, bicolour cultivars are common. The height commonly ranges from 7 inches to 3 feet; the dark green leaves are arranged in an alternate manner on the tall stem.

(www.agriculturalproductsindia.com/flowers/flowers-China-aster.html).

2.2 Plant Responses to Climatic Condition

Climate is fundamental to crop growth. Moisture stimulates seeds to germinate, the time to emergence being temperature-dependent. The rate of growth of roots, stem and leaves depends on the rate of photosynthesis, which in turn depends on light, temperature, moisture and carbon dioxide (CO_2). Temperature and daylength determine when plants produce leaves, stems and flowers, and consequently the filling of grain of the expansion of fruit (Sprigate and Kover, 2013).

Light intensity influences the manufacture of plant food, stem length, leaf colour and flowering. Plant grown in low light tends to be spindly with light green leaves. A similar plant grown in very bright light tends to be shorter, better branches, and have larger, dark green leaves. The divisions of plants into three main classes are long-day plants (LDP), short-day plants (SDP) and day-neutral plants (DNP). LDP may be defined as plants which flower or show accelerated flowering as result of an increase in daylength beyond a critical value, and obviously SDP flowers shows accelerated flowering with a shortening of the photoperiod below a critical value. A DNP is a plant which flowers independent of the photoperiod. China asters are normally classified as long day plants (Poesch and Laurie, 1935). However, research indicates that asters will flower under short day conditions but will produce small, stunted plants of little commercial value (Lin et al., 1950). China asters will flower at high temperatures even on the shortest daylengths of the year, but stems produced are short and thus long photoperiods are necessary for development of normal growth habit. The plants under long day treatment produced greater plant diameter and height than did plants grown under short days (Gruts and Joiner, 1960). Laurie and Foote (1935) reported that a reduction in number of long day photoperiods induced earliness in a number of varieties along with shorter stems and slightly smaller flowers. Beibel and Joseph, 1936 pointed out that the long day photoperiods had the greatest effect 18-45 days after aster seeds germinated. Lin and Watson (1950) found that flower initiation occurred earlier under long days than short days, 15 days earlier at high temperature (65°F) and 30 days earlier at low temperature (50°F).

Most plants tolerate normal temperature fluctuations. In general, foliage plants grow best between 70° and 80°F during the day and between 60° and 68°F at night. Most flowering plants prefer the day temperature rage, but grow best when night temperatures range from 55° to 60°F. Lower night temperatures help the plant to recover from moisture loss, intensify flower colour and prolong flower life. Excessively low or high temperatures may cause plant stress, inhibit growth, or promote a spindly appearance and foliage damage or drop. Cool night temperatures are actually more desirable for plant growth than high temperature. A good rule of thumb is to keep night temperatures 10° to 15°F lower than day temperatures.

2.3 Storage Materials

Good storage is a basic requirement in seed production program as the maintenance of high seed viability and vigour from the harvest to planting is of utmost important in a seed production program (Jaya, 2014). The type of storage container depends on storage conditions. Most seeds maintain their germination properties for several years even at quite high temperature if they are kept very dry. But when dry seeds in porous containers (burlap, cotton, paper) are removed from refrigerated and dehumidified storage, they absorb moisture rapidly from the atmosphere, which can impair their viability in a few days or weeks. Very dry seeds (3-8% moisture) kept in moisture proof containers retain good viability and vigor in different condition of temperature and humidity (Vaughon et al., 1967).

Packages designed to protect most physical qualities of seeds such as weight, size, colour, moisture content, and purity (freedom from weeds, inert matter, and diease organisms and damage), as well as their physiological aspects, like viability, vigor and dormancy, are made up of materials that have sufficient tensile strength, bursting strength, and tearing resistance to withstand normal pressure and handling produces. Such materials do not normally protect seeds against insect, rodents, changes in moisture unless special protective qualities are built into them.

Packaging materials used for storing seeds can be made of burlap, cotton cloth, paper, films, metal, glass, fiber board, or various combinations of materials. Some offer protection against moisture, whereas others do not. Each material has characteristics suitable for a particular type of package.

2.3.1 Materials freely permeable to moisture and gases

These include hessian or burlap sacks, cotton bags, nylon net sacks, Kraft paper bags, baskets of plant materials, plastics or metal, boxes of wood and containers made of paper, cardboard and fiberboard which have not been coated with wax or similar substances. The materials are used where good air circulation is required (Lauridsen et al., 1992).

2.3.2 Materials completely impermeable to moisture and gases when sealed

These containers include metal cans and drums (iron, tin or aluminium), glass jars, and laminated foil packages. Only metal cans and glass bottles with tight-sealing threaded caps, and good quality laminated aluminium foil can be recommended for long-term storage. However, containers are only as moisture-proof as their sealing. It is always essential to examine the lid, seal, and the rim of cans or jars. There will often be burrs or groves on cans and jars. The seal may not be of the right material, or it may not remain firmly in position. As faultless and sealed containers of these materials have no openings, they provide full protection against loss of seed and against contamination from outside (Lauridsen et al., 1992).

2.3.3 Materials partially impermeable to moisture and gases

This group includes primarily plastics: polyethylene = polythene (PE), polypropylene, polyester (PET), polyamide (nylon) (PA), and polyvinylidene chloride (PVC).

PE, in its low density form, has a relatively low water-vapour transmission rate but the permeability to gases is high. High density PE is more resistant to water penetration than regular PE of the same thickness. The permeability of PE changes with the temperature; thus the lower the temperature, the better the resistance to water vapour; and the higher the relative humidity of the surroundings the faster is the moisture transmission into the bag .

Soft PVC (i.e. PVC with a certain amount of plasticiser) has high permeability. The permeability to moisture and gases of plastic and polythene containers will depend on the type of material together with the thickness of the material (Lauridsen et al., 1992). Polythene bags have been used with good results for up to 5 years' storage of *Pinus caribaea* in Honduras. A thickness of 100-125 μ is recommended, as thinner polythene can permit a significant passage of water vapour in time and is also subject to mechanical damage in handling (Robbins 1983). Harrington (1973) considered 75 μ high density or 125 μ regular density for temperate conditions, and 175 μ high density or 250 μ regular as adequate for even severe tropical conditions.

2.4 Effect of Storage Materials on Seed Storage Quality

Although seed quality is governed by genetic make-up, commonly the quality of seeds is deteriorated during storage period. Poor storage conditions greatly affect seed vigour (Heydecker, 1979). The deterioration rate depends on storage condition including temperature, relative humidity, seed moisture contents, storage container types, etc. Types of container also regulate temperature, relative humidity, and seed moisture contents. High temperature, relative humidity, and moisture in the storage environment appear to be principle factors involved in deterioration of seed quality. Seed health has been found to be influenced by the seed quality (Fakir, 1989). Storage materials are also known to influence seed storage potential in several field and horticultural crops including flower crops.

Palaniswamy et al. (1995) reported that tomato seed stored in polythene bag (700 gauge) maintained higher seed viability (60%) even after 12 months of storage than the seeds stored in cloth bag.

Marigold seeds with 7±0.5 per cent moisture content maintained viability up to 6 months when stored in cloth bags and for a longer period when stored in polythene bag (Selvaraju et al., 1999).

Kumbar (1999) reported in chickpea that, the seed quality decreased with increase in storage period in all the cultivars. Polythene lined gunny bag recorded significantly higher germination (76.30%), speed of germination (16.01), root length (16.28 cm), shoot length (6.35 cm), vigour index (1723), and dry weight (171 mg/seedling).

Patil (2000) reported that chickpea seeds stored in polythene bag maintained higher quality parameters with lesser quantitative losses than the seeds stored in cloth bag. Annigeri–1 stored in polythene bag recorded higher germination (67.68%) and vigour index (1504) with less moisture content (9.27%) at the end of fourteen month of storage period.

Mettananda et al. (2001) reported that the lowest storability was recorded from seeds stored in woven polypropylene sacks (poly-sacks) with 12% moisture whereas the highest storability was from seeds packed in clear polythene with 8% moisture content in maize.

Hunje (2002) reported that seeds stored in sealed aluminium foil pouches recorded significantly higher germination (89.67%), root length (9.77 cm), shoot length (8.55 cm) and vigour index (1643) at the end of 20 months of storage period compared to seed stored in fruit form in chilli.

Sharanamma (2002) noticed in chilli that seeds stored in 700 guage polythene bag recorded higher seed quality parameters compared paper bag.

Bharathi (2002) reported in gaillardia that, the seed quality decreased with increase in the storage period. However, significantly higher germination (69.33%), root length (3.1 cm), shoot length (3.48 cm), vigour index (456), dry weight (20.45 mg) and germination rate index (13.95) were recorded in seeds stored in two layer polythene packet (400 gauge) with silica gel at the end of storage period.

Mersal et al. (2006) found that prolonging storage period and high seed moisture content reduced germination, seedling vigour and accelerated seed ageing.

Singh et al. (2011) pointed out that germination was decreased during storage period in wheat.

Naguib et al. (2011) reported that wheat seed stored in aluminium and polyester bags showed high seed germination, seedling vigour and kept nutrient contents, and therefore they could delay seed quality deterioration compared with plastic and cloth bags.

3. MATERIALS AND METHODS

Three sets of experiment were conducted at the Department of Horticulture and Agricultural Biotechnology, Yezin Agricultural University, Naypyitaw (19˚ 15'N and 0˚ 7'E). The soil type is sandy loam with a pH value of 6.25.

3.1 Experiment I: Study on Phylogenic Relationship of China Aster

A field experiment was carried out at the Department of Horticulture and Agricultural Biotechnology from October 2012 to January 2013. The experiment was conducted by using a Randomized Complete Block Design with four replications. There were four treatments based on collection of seed sources from four different areas in this experiment and the treatments were as follows:

T_1 - Yangon seed source (YGN)

T_2 - Taungoo seed source (TGO)

T_3 - Pyinmana seed source (PMA)

T_4 - Pyin-Oo-Lwin seed source (POL)

3.1.1 Experimental procedure- The seeds were collected from four different sources (Yangon, Taungoo, Pyinmana and Pyin-Oo-Lwin). The nursery bed was thoroughly prepared and mixed with chicken manure, sand and burnt rice husk. China aster seeds were sown in the nursery bed and covered with straw to prevent moisture loss. The nursery beds were watered twice in the morning and evening for the first 10 days. After 10 days, watering was done only in the morning. Straw was removed just after seed emergence. Hand weeding was done at 20 days after sowing. The seedlings were ready for transplanting at 35days after sowing.

The experimental plot was brought to fine tilth by ploughing and repeated harrowings. The experimental plots were laid out according to the treatments. Fertilizers were applied 4 times: basal and 3 times side dressings based on the recommended rate (180: 120: 100 kg/ha N: P_2O_5: K_2O) in the form of urea, single super phosphate and muriate of potash (Mantur, 1988). For basal application, all of single super phosphate, chicken manure and burnt rice husk were applied to each experimental plot. Thirty five days old seedlings were transplanted at a spacing of 25 cm between the rows and 25 cm between the plants. Transplanting was done in the evening by using two seedlings per hill and then mulching was done with straw. Light irrigation was given after transplanting. The transplants were watered twice in the morning and evening for the first 10 days and daily once after that period. Thinning was done at 10 days after transplanting by leaving one healthy plant per hill. Side dressings were done at 10, 20 and 30 days after transplanting (DAT). At each side dressing, 1/3 of urea and 1/3 of potash were applied to each plot.

Hand weeding was carried out throughout the growth period whenever it was necessary. Insecticide such as endosulfan 35 EC at the rate of 2 ml.L^{-1} of water was used against leaf hopper, aphids, thrips and mites. Spraying was done 2 times: at 15 and 30 DAT. Soil drenching was also taken up with Bavistin at the rate of 2 ml.L^{-1} of water against *Fusarium* wilt at 45 DAT.

Harvesting of capitula for seed production was done at 90 DAT. The fully dried flowers were harvested and sun dried for three days. The dried flowers were threshed, cleaned and separated from chaffy seeds. The cleaned and filled seeds were stored in brown bottle under ambient condition for next experiments.

3.1.2 Data collection

The following data were collected.

i. Plant height (cm)
ii. Number of branches per plant
iii. Number of leaves per plant
iv. Canopy diameter (cm)
v. Days to floral bud initiation
vi. Days to first flower opening
vii. Days to 50 per cent flowering
viii. Number of flowers per plant
ix. Flower diameter (cm)

Nine plants were randomly selected from each treatment and they were tagged for recording.

Plant height: it was recorded in centimeter from the ground level to the tip of the plant.

Number of leaves per plant: it was counted on the number of expand leaves from the main stem.

Number of branches per plant: it was noted on the number of primary branches arising from the main stem.

Days to floral bud initiation: it was recorded by counting the number of days from the date of transplanting to the slight swelling at the tip of the stem.

Days to first flower opening: it was recorded by counting the number of days from the date of transplanting to the first floret unfurling.

Days to 50% flowering: it was recorded by counting the number of days from the date of transplanting to 50% of flower opening.

Number of flowers per plant: it was recorded as the number of open flowers per plant.

Flower diameter: it was measured at the point of maximum breadth of the flower. This was measured by using Vanier calliper.

3.1.3 Statistical analysis

The UPGMA algorithm was used to construct a phylogram for four seed sources of China aster by using shared allele distances with MEGA 4 software (4.0) (Tamura et al. 2007) embedded in Power Marker (3.2) (Liu and Muse, 2005).

3.2 Experiment II: Evaluation on Horticultural Traits of China Aster at Two Different Growing Seasons

Field experiments were carried out from October 2013 to August 2014 at the Department of Horticulture and Agricultural Biotechnology, Yezin Agricultural University. A Randomized Complete Block design with four replications was used. There were three treatments in both growing seasons. Experiment II A was carried out in winter season (October, 2013 to January, 2014). Experiment II B was carried out in rainy season (May, 2014 to August, 2014).

Growing seasons

Experiment II A – Winter season

Experiment II B – Rainy season

Treatments

Seed Sources

T_1 – Yangon seed source (YGN)

T_2 – Taungoo seed source (TGO)

T_3 – Pyinmana seed source (PMA)

3.2.1 Experimental procedure - According to the cluster analysis in the first experiment, *Callistephus* accessions clustered into three main groups in UPGMA phylogram. Group I and II (GI and II) include seeds collected from Pyin Oo Lwin while group III (GIII) includes seeds from Yangon, Taungoo and Pyinmana. Based on cluster analysis, the second experiment (Expt. II A and II B) was carried out at two different growing seasons by using the seed sources from Group III (G III) since they showed the same morphological characters. Crop management practices were the same as those used in the first experiment. In experiment II A, harvesting of capitula for seed was done at 90 DAT (days after transplanting). The fully dried flowers were harvested and sun dried for three days. The dried flowers were threshed, cleaned and filled seeds were separated from chaffy seeds. Filled seeds were used for assessing seed quality parameters. In experiment II B, harvesting of cut flower was done at 60 DAT (after 50% flower opening on each treatment). Harvesting was carried out three times in both experiments II A and B.

3.2.2 Data collection

Data collection of the second experiment was the same as that used in the first experiment.

3.2.3 Statistical analysis

The data were analyzed statistically through ANOVA using SAS program (9.1), and means were compared by using Least Significant Difference (LSD) test at $P < 0.05$.

3.3 Experiment III: Effect of Storage Materials on Seed Storage Quality of China Aster

This experiment was conducted at the Department of Horticulture and Agricultural Biotechnology from March to August 2014. Three different seed sources of China aster were stored under ambient condition by using five storage materials for about six months.

Treatments

Factor A: Seed sources

T_1 – Yangon seed source (YGN)

T_2 – Taungoo seed source (TGO)

T_3 – Pyinmana seed source (PMA)

Factor B: Storage materials

Pap – Paper bag

Alu – Aluminum foil bag

Bot – Bottle

Pol – Polythene bag

Clo – Cloth bag

3.3.1 Experimental procedure – The seed quality was evaluated by using germination test, measuring the seedling length and counting the number of days to germinate. Germination test was carried out by using 100 seeds from each treatment. The seeds were stored from March to August 2014 (six months). Monthly observation was made to determine the seed quality. The initial seed quality parameters were ascertained before conducting storage studies. The initial observations on seed quality parameters are presented below (Table 1).

Table 1 Seed quality parameters of China aster seeds before seed storage

Seed Sources	Germination percentage (G%)	Germination index (GI)	Seedling vigour index (SVI)
Yangon	88.50	41.23	376.75
Taungoo	95.00	41.44	391.75
Pyinmana	94.50	40.85	401.75

3.3.2 Data collection

The following data were recorded using the collection procedure mentioned below.

i. Germination (%) (G%)
ii. Germination index (days) (GI)
iii. Seedling length (cm) (SL)
iv. Seedling vigor index (SVI)

One hundred China aster seeds were placed on wetted cotton wool in the Petri dishes covered with caps. The germination and seedling growth were daily observed for 10 days. The number of seeds germinated in each Petri dish was counted and germination index was calculated according to Heydecker (1969). After being seedling emergence for 10 days, the seedling length was measured from 10 normal seedlings of each replication. It was measured from shoot tip to root tip. Seedling vigour index was calculated by using the formula suggested by International Seed Testing Association (ISTA 1993).

$$GI = \frac{N_1}{D_1} + \frac{N_2}{D_2} + ---- + \frac{N_n}{D_n}$$

N_1, N_2 ------ N_n: Number of emerged seedlings on 1^{st}, 2^{nd} and n^{th} day after sowing

D_1, D_2 ------ D_n: Number of days after sowing

SVI = Germination (%) x Seedling length (cm)

SVI = Seedling vigour index

3.3.3 Statistical analysis

The collected data were analyzed statistically through ANOVA using SAS program (9.1) and mean data were compared by using Least Significant Difference (LSD) test at $P < 0.05$.

(a) Paper bag

(b) Aluminum foil bag

(c) Bottle

(d) Polythene bag

(e) Cloth bag

Plate 1 Different type of storage materials

4. RESULTS

4.1 Experiment I: Study on Phylogenic Relationship of China Aster

4.1.1 Flower and stem colour variation of China aster

Variation of flower colour and stem colour of China aster was observed among the seed sources. Four different lower colours were observed: white, red, light pink and dark pink (Figure 1). Two different stem colours were observed: green and red (Figure 2). Five colour variations were resulted in combination with stem colour and flower colour: light pink flower with red stem, dark pink flower with red stem, red flower with red stem, light pink flower with green stem and white flower with green stem (Figure 3). Yangon, Taungoo and Pyinmana (YGN, TGO, PMA) seed sources showed 43 to 55 % of dark pink flower with red stem, 35 to 47% of light pink flower with red stem, 5 to 11% of red flower with red stem and 1 to 4 % of light pink flower with green stem. However, 65% of light pink flower with green stem, 22% of white flower with green stem and 15% of light pink flower with red stem were found in Pyin-Oo-Lwin (POL) seed source.

4.1.2 Cluster analysis

Figure 4 represents that UPGMA (unweighted pair-group) dendrogram showing phylogenic relationships among *Callistephus* accessions. The phylogenic relationship was constructed based on horticultural traits such as plant height, number of leaves, number of branches, canopy diameter, number of flowers, flower diameter, days to floral bud initiation, days to first flower opening and days to 50 percent flowering. The analysis indicated that *Callistephus* accessions clustered into three main groups in UPGMA phylogram. Maximum accessions were in Group III involving twenty seven accessions, followed by Group II with six accessions and Group I with three accessions. The accessions A from Yangon (YGN), accessions B from Taungoo (TGO), accessions C from Pyinmana (PMA) and accession D from Pyin-Oo-Lwin (POL). Pyin-Oo-Lwin (POL) seed source was included in Group I and II while those Yangon, Taungoo and Pyinmana (YGN, TGO, PMA) seed sources were included in Group III.

4.1.3 Analysis of variance (ANOVA)

The analysis of variance for each source showed that the effects of accessions were highly and significantly different for all characters except the number of leaves (Table 2). When quantitative characters were subjected to the analysis of variance, number of branches, canopy diameter, number of flowers, flower diameter, days to bud initiation and days to 50 percent flowering were highly significant at 1% level. Plant height and days to first flower opening were significant at 5% level. Number of leaves was not significant among the 36 China aster accessions. The coefficient of variation (CV%) was maximum in both characters (number of branches and number of flowers) (13.05%), followed by number of leaves (11.82%), plant height (10.35%) and minimum in flower diameter (1.86%). The coefficient of determination (R^2) value ranges from 0.65 to 0.98.

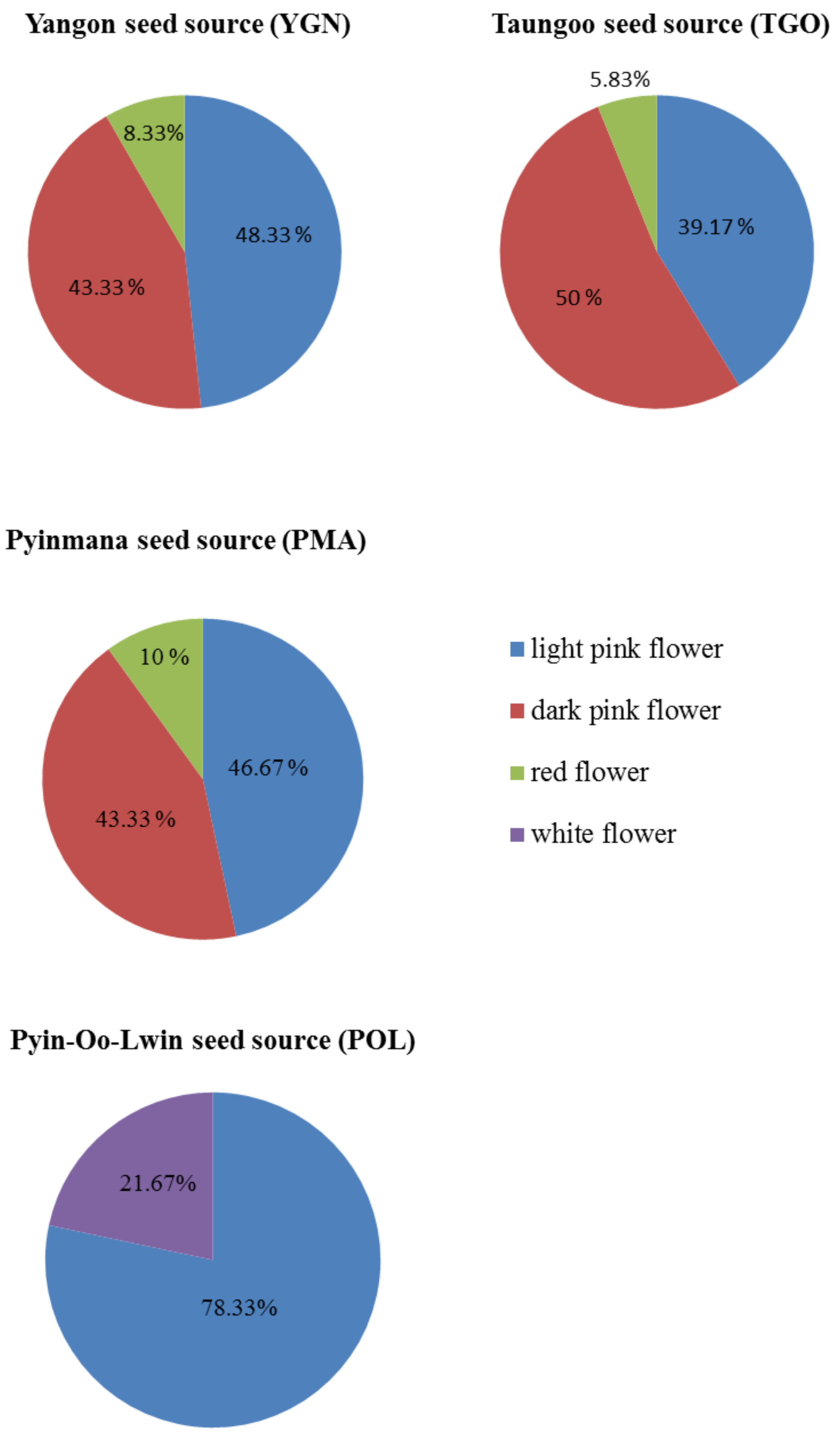

Figure 1 Variation of flower colour of China aster depending on different seed sources

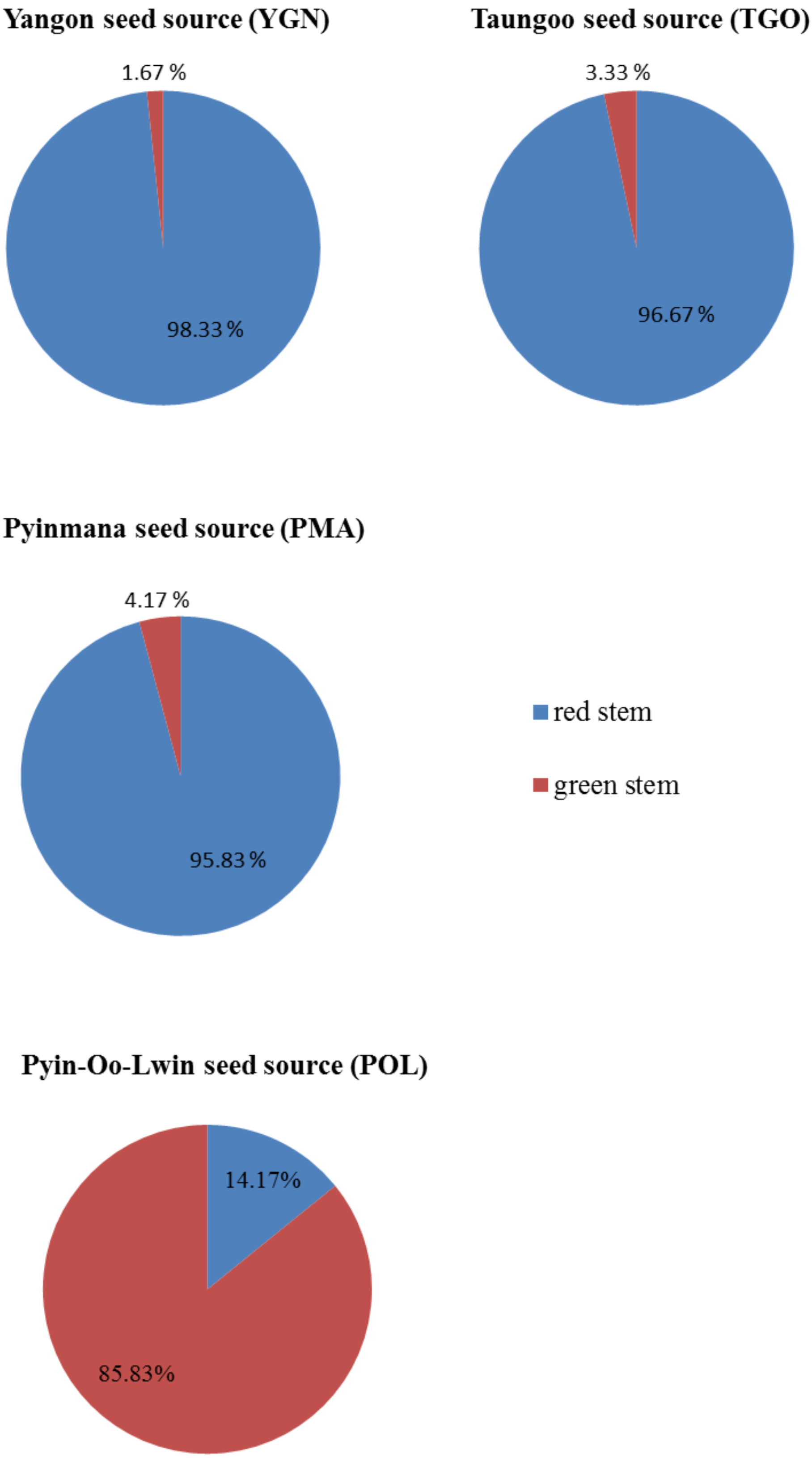

Figure 2 Variation of stem colour of China aster depending on different seed sources

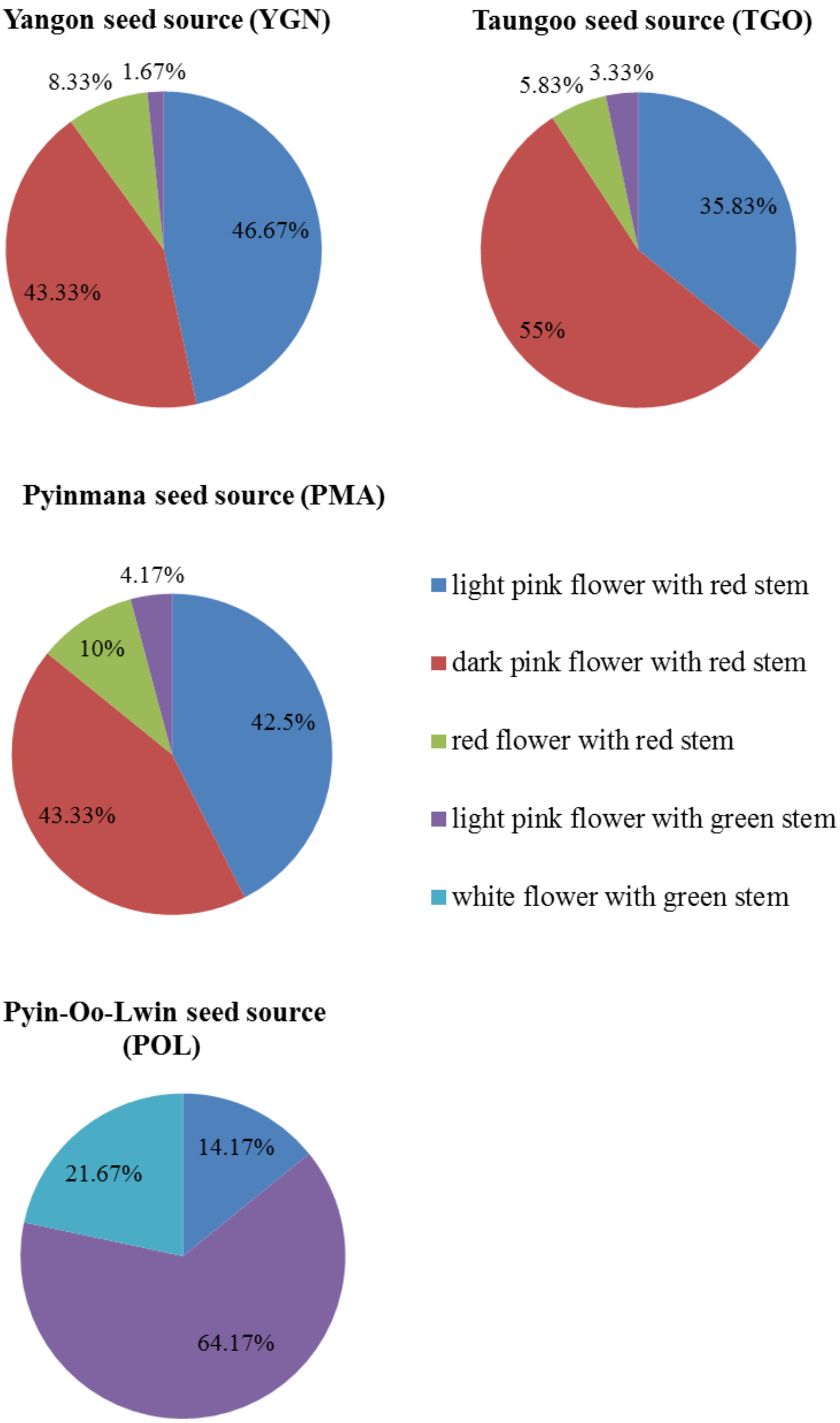

Figure 3 Variation of flower and stem colour of China aster depending on different seed sources

(a) Light pink flower with red stem

(b) Light pink flower with green stem

(c) Red flower with red stem

(d) Dark pink flower with red stem

(e) White flower with green stem

Plate 2 Different colours of China aster

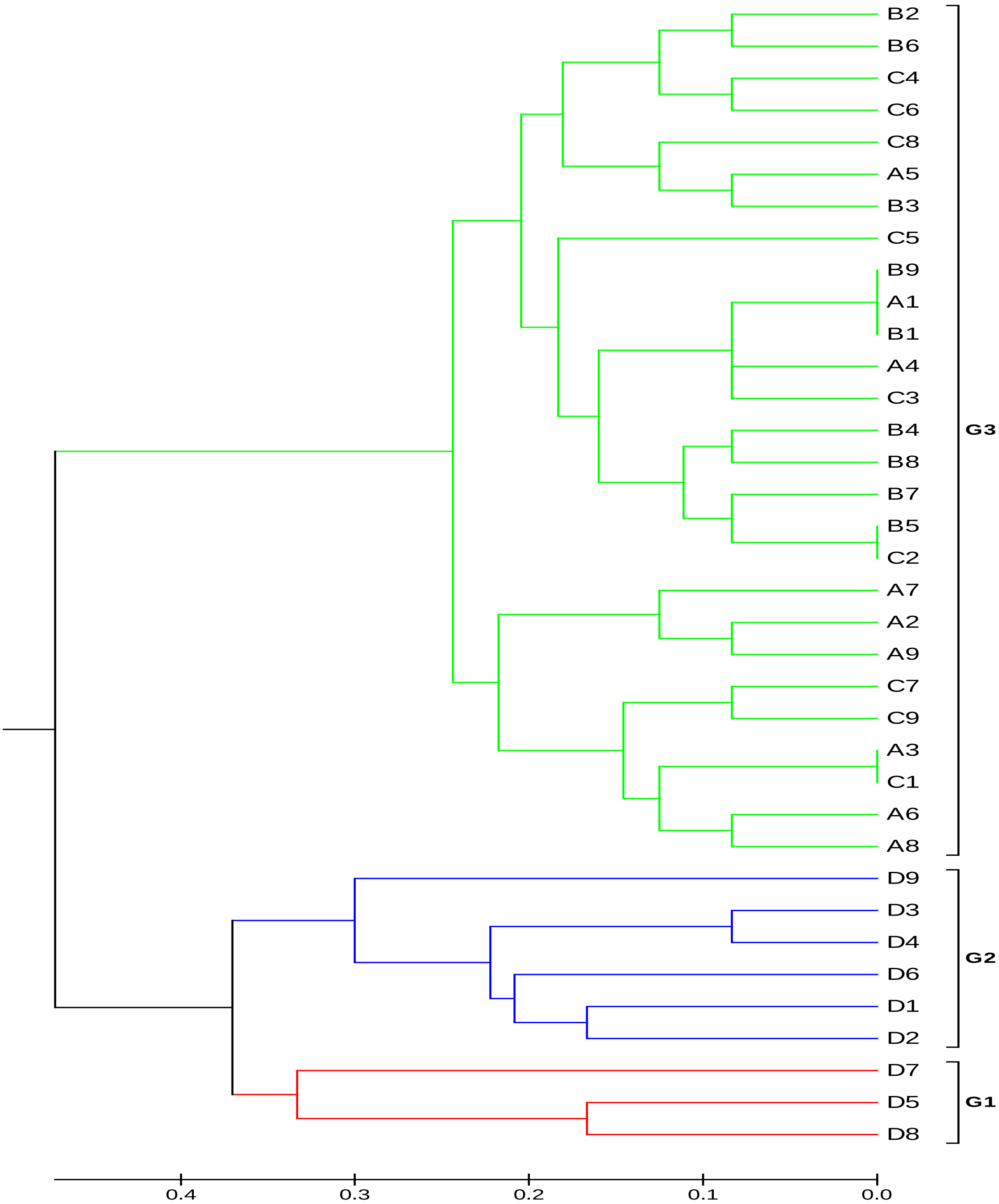

Figure 4 UPGMA (unweighted pair-group) dendrogram showing phylogenic relationships among *Callistephus* accessions

Table 2 Analysis of variance (ANOVA) for 9 quantitative traits for 36 China aster accessions

No.	Characters	Mean Square for Source of Variation				
		Replications	Accessions	Residual	R^2	CV%
1.	Plant height (cm)	6.02	185.01*	32.19	0.75	10.35
2.	No. of leaves/plant	5.89	18.54ns	6.00	0.65	11.82
3.	No. of branches/plant	0.56	35.48**	2.67	0.87	13.05
4.	Canopy diameter/plant (cm)	8.02	559.90**	3.84	0.98	5.73
5.	No. of flowers/plant	0.50	35.48**	2.67	0.87	13.05
6.	Flower diameter (cm)	0.49	1.45**	0.02	0.98	1.86
7.	Days to floral bud initiation	10.04	197.12**	3.06	0.97	3.93
8.	Days to first flower opening	23.50	68.64*	9.39	0.82	4.75
9.	Days to 50% flowering	19.75	109.67**	3.75	0.94	2.83
	d.f.	2	3	6		

* = Significant at P (0.05)

** = Highly significant at P (0.01)

ns = Non-significant

4.2 Experiment II: Evaluation on Horticultural Traits of China Aster at Different Growing Seasons

4.2.1 Growth parameters

4.2.1.1 Plant height

Variation in plant height of China aster as influenced by seed sources, growing seasons and their interaction effects are presented in Table 3.

Growing season had a great impact on plant height of China aster. Highly significant differences of plant height were observed between two different growing seasons (winter and rainy seasons). Plant height of China aster growing at winter season was significantly higher than those growing at rainy season. In winter season, the average number of plant height was recorded 51.00 cm while it was 43.83 cm in rainy season. In winter season, plant height was significantly different among the seed sources. Maximum plant height was observed in Pyinmana seed source (54.45 cm) followed by Yangon seed source (52.56 cm), and they were significantly different from Taungoo seed source (46.00 cm). In rainy season, no significant difference of plant height was observed among the varieties. Plant height ranged from 40.53 cm to 45.53 cm. The highest plant height was observed in Taungoo seed source (45.53 cm) and followed by Yangon seed source (45.43 cm) and Pyinmana seed source (40.53 cm). Plant height showed no significant interaction between the growing season and seed sources at different evaluation periods except 10 WAT.

Table 3 Comparison of plant height of China aster at two different growing seasons

Seed sources	Plant height (cm)				
	Weeks after transplanting (WAT)				
	2	4	6	8	10
Winter Season					
YGN	10.83 a	19.42 ab	37.75	49.61 ab	52.56 a*
TGO	10.97 a	22.95 a	34.68	45.61 b	46.00 b
PMA	9.14 b	17.64 b	34.03	51.80 a	54.45 a
Mean	10.31	20.00	35.49	40.01	51.00
$LSD_{0.05}$	1.35	3.89	5.93	5.89	5.88
Rainy Season					
YGN	6.30	11.93	28.99	43.63	45.43
TGO	6.09	11.94	24.04	39.39	45.53
PMA	6.29	11.41	24.59	34.44	40.53
Mean	6.23	11.76	25.87	39.15	43.83
$LSD_{0.05}$	1.79	4.85	12.35	16.48	10.21
Pr>F					
Seasons	<.0001	0.0003	0.002	0.002	0.009
Seed Sources	0.15	0.11	0.29	0.77	0.43
Seasons x Seed sources	0.10	0.19	0.94	0.23	0.05
CV%	11.09	16.00	18.24	16.23	10.16

* Means in the same column followed by the same letters are not significantly different at 5% level of LSD.

YGN – Yangon seed source, TGO – Taungoo seed source, PMA – Pyinmana seed source

4.2.1.2 Number of leaves

Table 4 shows the number of leaves of China aster as influenced by seed sources, growing seasons and their interaction effects.

Growing season influenced on the number of leaves per plant of China aster. Significant differences of leaf number were observed between the two growing seasons (winter and rainy seasons). More number of leaves was noticed in winter season than in rainy season. Mean leaf number was observed as 19.75 in winter season and 16.45 in rainy season. In winter season, significant difference of leaf number was observed among the seed sources at an early growth stage (until 4 WAT). At 2 WAT and 4 WAT, Taungoo seed source showed the highest number of leaves (10.08 and 16.36) respectively and it was significantly different from Yangon seed source (9.67 and 15.61) and Pyinmana seed source (8.17 and 14.73). In rainy season, no significant difference of leaf number was found among the seed sources throughout the growth stages. The highest number of leaves was found in Pyinmana seed source (16.83) followed by Taungoo seed source (16.75) and Yangon seed source (15.78). The number of leaves showed significant interaction between the growing season and seed sources only at 2WAT and no significant interaction at other growth stages.

Table 4 Comparison of number of leaves of China aster at two different growing seasons

Seed Sources	Number of leaves				
	Weeks after transplanting (WAT)				
	2	4	6	8	10
Winter Season					
YGN	9.67 a*	15.61 ab	20.86	21.02	21.03
TGO	10.08 a	16.36 a	18.90	18.99	18.99
PMA	8.17 b	14.73 b	19.00	19.19	19.23
Mean	9.31	15.57	19.59	19.73	19.75
$LSD_{0.05}$	1.32	1.29	4.40	4.12	4.08
Rainy Season					
YGN	5.52	10.40	15.80	15.78	15.78
TGO	5.78	10.60	16.70	16.75	16.75
PMA	5.67	10.15	16.80	16.83	16.83
Mean	5.66	10.38	16.43	16.45	16.45
$LSD_{0.05}$	0.49	3.27	1.91	1.87	1.87
Pr>F					
Seasons	<.0001	0.0009	0.001	0.0008	0.0009
Seed Sources	0.02	0.38	0.86	0.84	0.84
Seasons x Seed Source	0.02	0.72	0.27	0.23	0.22
CV%	7.7	11.07	10.89	10.21	10.14

* Means in the same column followed by the same letters are not significantly different at 5% level of LSD.

YGN – Yangon seed source, TGO – Taungoo seed source, PMA – Pyinmana seed source

4.2.1.3 Number of branches

Differences in the number of branches of China aster as influenced by seed sources, growing seasons and their interaction effects are shown in Table 5.

Growing season showed a great influence on the number of branches of China aster. Significant differences of the number of branches were recorded between the two different growing seasons (winter and rainy seasons). Numbers of branches were more in rainy season than in winter season. The average numbers of branches at 10 WAT were recorded as 10.12 in winter and 14.28 in rainy season. However, the number of branches among the seed sources was not significantly different in both winter and rainy seasons. In winter season, the highest number of branches was noticed in Yangon seed source (10.81) and followed by Pyinmana seed source (9.95) and Taungoo seed source (9.61). In rainy season, the highest number of branches was recorded in Taungoo seed source (15.70) followed by Pyinmana seed source (14.15) and Yangon seed source (12.98). The number of branches showed no significant interaction between the seed sources and growing seasons at all growth stages.

Table 5 Comparison of number of branches of China aster at two different growing seasons

Seed Sources	Number of branches		
	Weeks after transplanting (WAT)		
	6	8	10
Winter Season			
YGN	7.86	9.64	10.81
TGO	7.31	8.67	9.61
PMA	5.72	8.55	9.95
Mean	6.96	8.95	10.12
$LSD_{0.05}$	2.67	2.68	3.17
Rainy Season			
YGN	8.58	12.10	12.98
TGO	5.98	14.15	15.70
PMA	6.33	13.73	14.15
Mean	6.96	13.33	14.28
$LSD_{0.05}$	3.31	4.87	4.14
Pr>F			
Seasons	0.99	0.007	0.001
Seed Sources	0.07	0.89	0.75
Seasons x Seed Sources	0.44	0.37	0.22
CV%	25.00	20.41	17.45

YGN – Yangon seed source, TGO – Taungoo seed source, PMA – Pyinmana seed source

4.2.1.4 Canopy diameter

Canopy diameter of China aster as influenced by seed sources, growing seasons and their interaction effects are presented in Table 6.

Growing season had no significant impact on canopy diameter of China aster. Canopy diameter at rainy season (29.00 cm) was relatively greater than that at winter season (26.78) though they are not significantly different. Similarly, canopy diameter was not significantly different among the seed sources in both growing seasons. In winter season, the widest canopy diameter was recorded in Yangon seed source (27.64 cm) followed by Pyinmana seed source (26.80 cm) and Taungoo seed source (25.90 cm). Similarly in rainy season, the widest canopy diameter was observed in Yangon seed source (29.47 cm) followed by Pyinmana seed source (29.39 cm) and Taungoo seed source (28.14). It did not show significant interaction between the growing season and seed sources for all growth stages.

Table 6 Comparison of canopy diameter per plant of China aster at two different growing seasons

Seed Sources	Canopy diameter (cm)		
	Weeks after transplanting (WAT)		
	6	8	10
Winter Season			
YGN	24.89	27.51	27.64
TGO	23.95	25.45	25.90
PMA	24.49	26.55	26.80
Mean	24.44	26.50	26.78
$LSD_{0.05}$	4.57	3.74	3.53
Rainy Season			
YGN	25.18	28.36	29.47
TGO	25.03	26.99	28.14
PMA	25.42	28.38	29.39
Mean	25.21	27.91	29.00
$LSD_{0.05}$	1.52	1.64	2.06
Pr>F			
Seasons	0.49	0.22	0.07
Seed Sources	0.84	0.15	0.21
Seasons x Seed Sources	0.91	0.83	0.90
CV%	7.92	6.14	5.99

YGN – Yangon seed source, TGO – Taungoo seed source, PMA – Pyinmana seed source

4.2.2 Flowering and yield components

4.2.2.1 Days to floral bud initiation

Changes in days to floral bud initiation of China aster as influenced by seed sources, growing seasons and their interaction effects are presented in Table 7.

Number of days to floral bud initiation varied significantly depending on the growing season. China asters growing at rainy season initiate floral buds earlier than those growing at winter season. The average number of days to floral bud initiation was 41.87 in winter while it was 35.49 days in rainy season. In both growing seasons, days to floral bud initiation were significantly different among the seed sources. Taungoo seed source showed earlier bud initiation (39.75 days) and it was significantly different from Pyinmana seed source (42.44 days) and Yangon seed source (43.42 days) in winter season. However, the latest days to floral bud initiation were recorded in Taungoo seed source (36.03) and it was significantly different from Pyinmana seed source (35.23) and Yangon seed source (35.22) in rainy growing season. Number of days to floral bud initiation showed significant interaction between the growing season and seed sources.

4.2.2.2 Days to first flower opening

Table 7 represents days to first flower opening of China aster as influenced by seed sources, growing seasons and their interaction effects are presented in.

High significant differences of days to first flower opening were noticed between two different growing seasons (winter and rainy seasons). Plants growing at rainy season showed earlier flower opening than those growing at winter season. In winter season, it took 63.37 days to first flower opening while it was only 51.15 days in rainy season. Days to first flower opening did not differ significantly among the seed sources in both growing seasons. Yangon seed source showed 64.64 days to open the first flower and Pyinmana seed source took 64.58 days and Taungoo seed source took 60.89 days at winter season. In rainy season, number of days to first flower opening was short. It took only 49.65 to 52.30 days. Results indicated that there was no significant interaction between seed sources and growing seasons.

4.2.2.3 Days to 50 percent flowering

The results showed that the number of days to 50 percent flowering of China aster is influenced by the growing season (Table 7).

High significant differences of days to 50 percent flowering were recorded between the two different growing seasons (winter and rainy seasons). Plants growing in winter season took more days to 50 percent flowering than those growing in rainy season. It took 65.50 days in winter while it was only 55.25 days in rainy season. Days to 50 percent flowering showed no significant differences among the seed sources in winter season. It ranges from 63.75 to 66.50 days. However, significant difference was observed among the seed sources in rainy season. Pyinmana and Taungoo seed sources showed 56.25 days and it was 4 days later than Yangon seed source (52.75 days). Significant interaction was observed between the seed sources and growing seasons.

Table 7 Comparison of days to floral bud initiation, days to first flower opening and days to 50% flowering of China aster at two different growing seasons

Seed Sources	Days to floral bud initiation	Days to first flower opening	Days to 50% flowering
Winter Season			
YGN	43.42 a*	64.64	66.50
TGO	39.75 b	60.89	63.75
PMA	42.44 ab	64.58	66.25
Mean	41.87	63.37	65.50
$LSD_{0.05}$	3.44	5.04	4.53
Rainy Season			
YGN	35.22 b	49.65	52.75 b
TGO	36.03 a	51.50	56.25 a
PMA	35.23 b	52.30	56.75 a
Mean	35.49	51.15	55.25
$LSD_{0.05}$	0.49	3.04	2.51
Pr>F			
Seasons	0.0002	<.0001	0.002
Seed Sources	0.15	0.18	0.08
Season x Seed Sources	0.023	0.082	0.001
CV%	3.67	4.18	3.56

* Means in the same column followed by the same letters are not significantly different at 5% level of LSD.

YGN – Yangon seed source, TGO – Taungoo seed source, PMA – Pyinmana seed source

4.2.2.4 Number of flowers

Number of flowers of China aster as influenced by seed sources, growing seasons and their interaction effects are presented in Table 8.

The number of flowers varied greatly depending on the growing season. The flower number was significantly higher in the rainy season than in winter season. Number of flowers was 10.22 in winter and 14.28 in rainy season. Number of flowers did not show significant differences among the seed sources in both growing seasons. The maximum number of flower was observed in Yangon seed source (10.72) followed by Pyinmana seed source (10.11) and Taungoo seed source (9.83) in winter growing season. In rainy season, maximum number of flowers was observed in Taungoo seed source (15.70) followed by Pyinmana seed source (14.15) and Yangon seed source (12.98). No interaction effect between the seed sources and growing seasons was observed.

4.2.2.5 Flower diameter (cm)

Flower diameter of China aster as influenced by plant varieties, growing seasons and their interaction effects are presented in Table 8.

Significant variation of flower diameter was observed at two different growing seasons (winter and rainy season). The diameter of flower from plant grown in winter season was bigger than that from plant grown in rainy season. Flower diameter was recorded 7.04 cm in winter and 5.39 cm in rainy season. No significant difference of flower diameter was noticed among the seed sources in both growing seasons. In winter season, maximum flower diameter (7.22 cm) was recorded in Taungoo seed source followed by Pyinmana seed source (6.95 cm) and Yangon seed source (6.94 cm). In rainy season, maximum flower diameter was observed in Pyinmana seed source (5.64 cm) followed by Yangon seed source (5.37 cm) and Taungoo seed source (5.16 cm). Non-significant interaction of growing seasons and seed sources was observed in flower diameter.

Table 8 Comparison of number of flowers and flower diameter of China aster at two different growing seasons

Seed Sources	No. of flowers	Flower diameter (cm)
Winter Season		
YGN	10.72	6.94
TGO	9.83	7.22
PMA	10.11	6.95
Mean	10.22	7.04
$LSD_{0.05}$	3.20	0.29
Rainy Season		
YGN	12.98	5.37
TGO	15.70	5.16
PMA	14.15	5.64
Mean	14.28	5.39
$LSD_{0.05}$	4.14	0.64
Pr>F		
Seasons	0.0018	0.0003
Seed Sources	0.69	0.60
Season x Seed Sources	0.28	0.06
CV%	17.46	4.59

YGN – Yangon seed source, TGO – Taungoo seed source, PMA – Pyinmana seed source

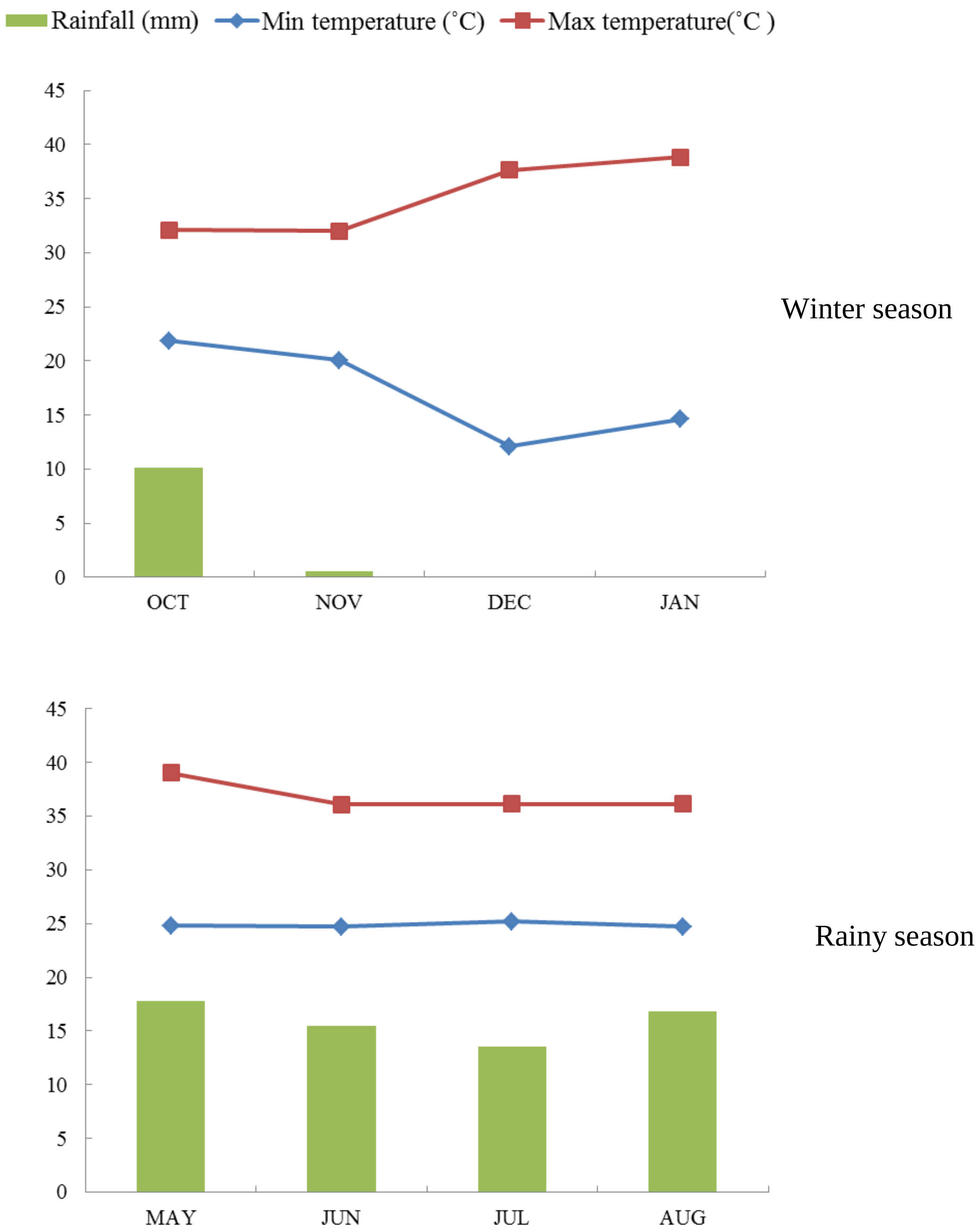

Figure 5 Minimum and maximum temperature (^{o}C) and monthly rainfall (mm) during the growing season

4.3 Experiment III: Effect of Storage Materials on Seed Storage Quality of China Aster

4.3.1 Germination percentage

It was observed that germination percentage differs as differences in seed sources and storage materials (Table 9). The interaction effect of seed sources and storage materials on germination percentage was also found.

Significant variation of germination percentage among the seed sources was observed starting from the early storage period up to the end of the experiment. The germination percentage of China aster seeds declined progressively with an increase in storage period in all seed sources irrespective of storage materials. The germination percentage of all seed sources decreased gradually starting from one month to six months after seed storage. Highest germination (89.1%) was noticed in Pyinmana seed source and it was significantly higher than Taungoo (88.6%) and Yangon (82.5%) seed sources at the first month after storage. At each seed evaluation period, significant variation of germination percentage was also observed among the seed storage materials. Significantly highest germination was observed in aluminium foil bag (85.17%) followed by polythene bag (84.17%) and the lowest germination (60.67%) was observed in cloth bag after six months of storage period respectively. Highly significant differences in seed germination were observed due to interaction between seed sources and storage materials during storage period.

Table 9 Germination% as affected by seed sources and storage materials

	Germination%					
	Months after storage (MAS)					
	1	2	3	4	5	6
Seed sources						
YGN	82.50	81.00 b	79.40 b	77.80 b	74.30	72.20
TGO	88.60 a	86.90 a	85.20 a	83.20 a	79.40	76.40
PMA	89.10 a	87.50 a	85.00 a	82.80 a	78.95	76.40
$LSD_{0.05}$	2.71	2.79	3.36	4.22	5.88	7.09
Storage materials						
Pap	83.50 a	81.83 a	78.83 b	76.33 b	68.33 c	64.50 c
Alu	90.50 a	89.17 a	87.83 a	87.00 a	86.00 a	85.17 a
Bot	87.67 a	85.67 b	85.17 a	83.83 a	82.42 b	80.50 b
Pol	89.67 a	88.17	87.00 a	86.17 a	84.83 ab	84.17 a
Clo	82.33 b	80.83 c	77.17 b	73.00 b	66.17 c	60.67 d
$LSD_{0.05}$	3.38	3.41	3.23	3.38	2.82	2.74
Pr>F						
Seed sources	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Storage materials	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Seed sources x Storage material	0.216	0.022	<.0001	0.0003	<.0001	<.0001
CV%	2.92	2.82	2.39	3.19	2.25	2.51

* Means in the same column followed by the same letters are not significantly different at 5% level of LSD.

YGN – Yangon seed source, TGO – Taungoo seed source, PMA – Pyinmana seed source

Pap – Paper bag, Alu – Aluminum foil bag, Bot – Bottle, Pol – Polythene bag, Clo – Cloth bag

4.3.2 Germination index

It is noted that germination index is influenced by storage materials only, not by seed sources and their interactions (Table 10).

The germination index did not show any significant difference among the seed sources at each evaluation period. The germination index decreased as the storage period increased in all seed sources irrespective of storage materials. Significant differences were observed among the storage materials starting from one month after seed storage to six months after seed storage. At one month after seed storage, the highest germination index was observed in aluminium foil (34.9) and it was significantly higher than that the seeds in polythene bag (31.43), bottle (28.66), cloth bag (26.37) and paper bag (24.36). Similar trend of germination index was observed until six month after seed storage. No interaction effect between the seed sources and seed storage materials was recorded.

Table 10 Germination index as affected by seed sources and storage materials

	Germination index (GI)					
	Months after storage (MAS)					
	1	2	3	4	5	6
Seed sources						
YGN	28.30	26.72	25.96	23.45	22.45	19.63
TGO	29.24	28.29	26.53	24.96	24.19	21.04
PMA	29.89	28.23	27.67	25.93	24.24	21.36
$LSD_{0.05}$	3.56	3.29	3.42	3.74	4.35	4.95
Storage materials						
Pap	24.36	26.08 c	23.02 cd	19.59 c	17.03 d	13.56 d
Alu	34.90 a	33.68 a	32.97 a	31.40 a	31.73 a	31.29 a
Bot	28.66	25.87 c	25.80 c	25.36 b	24.23 c	18.59 c
Pol	31.43 b	30.13 b	29.46 b	28.19 b	28.46 b	26.18 b
Clo	26.37	22.97 d	22.35 d	19.08 c	16.67 d	13.77 d
$LSD_{0.05}$	3.39	2.88	2.86	2.69	2.30	2.19
Pr>F						
Seed sources	0.60	0.33	0.42	0.12	0.41	0.14
Storage materials	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Seed x Storage Sources Mate	0.99	0.99	0.51	0.24	0.93	0.56
CV%	15.80	13.60	12.59	12.52	12.56	12.70

[*] Means in the same column followed by the same letters are not significantly different at 5% level of LSD.

YGN – Yangon seed source, TGO – Taungoo seed source, PMA – Pyinmana seed source

Pap – Paper bag, Alu – Aluminum foil bag, Bot – Bottle, Pol – Polythene bag, Clo – Cloth bag

4.3.3 Seedling vigour index

Seedling vigour indices differ greatly as differences in seed sources and storage materials. The interaction effect is also presented in Table 11.

The seedling vigour index showed significant differences among the seed sources up to 5 months of storage. The seedling vigour index decreased as the storage period increased in all seed sources irrespective of storage materials. The highest seedling vigour index was noticed in Taungoo seed source (319.25) followed by Pyinmana seed source (313.40) and Yangon seed source (299.35) at six months after storage. At each seed evaluation period, significant variation of seedling vigour index was observed among the seed storage materials. The highest seedling vigour index was recorded in aluminium foil (350.33) followed by polythene bag (347.67), bottle (328.92), paper bag (265.92) and cloth bag (260.50) at the end of six months seed storage. The interaction effect between seed sources and storage materials was recorded only at three evaluation periods (three, four and six months after storage).

Table 11 Seedling vigour index as affected by seed sources and storage materials

	Seedling vigour index (SVI)					
	Months after storage (MAS)					
	1	2	3	4	5	6
Seed sources						
YGN	351.25 b	344.30 b	331.25 b	322.80 b	306.40 b	299.35
TGO	374.00 a	376.00 a	362.95 a	347.90 a	325.85	313.40
PMA	374.05 a	365.40 a	361.20 a	348.60 a	340.20 a	319.25
$LSD_{0.05}$	19.41	20.94	21.21	20.79	29.52	29.16
Storage materials						
Pap	354.92 bc	348.00 c	331.75 bc	327.42 b	290.50 c	265.92 c
Alu	383.83 a	382.92 a	377.33 a	362.17 a	362.17 a	350.33 a
Bot	375.17 ab	356.42 bc	355.50 ab	352.50 a	336.83 b	328.92 b
Pol	368.08 abc	378.68 ab	369.67 a	355.75 a	361.00a	347.67 a
Clo	350.17 c	343.58 c	324.75 c	301.00 c	270.25 c	260.50 c
$LSD_{0.05}$	24.93	26.39	24.82	21.49	23.98	17.92
Pr>F						
Seed sources	0.03	0.008	<.0001	0.0003	0.0003	0.005
Storage materials	0.15	0.067	0.0003	0.0001	<.0001	<.0001
Seed Sources x Storage Materials	0.48	0.65	<.0001	0.023	0.08	0.04
CV%	7.98	8.45	5.36	6.05	7.28	5.95

[*] Means in the same column followed by the same letters are not significantly different at 5% level of LSD.

YGN – Yangon seed source, TGO – Taungoo seed source, PMA – Pyinmana seed source

Pap – Paper bag, Alu – Aluminum foil bag, Bot – Bottle, Pol – Polythene bag, Clo – Cloth bag

5. DISCUSSION

The crop growth, seed yield and quality parameters are directly or indirectly controlled by the environment in which crops are grown. In addition genotype, soil fertility, nutrition, cultural practices and their interactions exhibit a profound influence on growth, flowering and productivity of crop plants. Three experiments were conducted to determine the phylogenic relationship, horticultural traits and seed quality of China aster varieties. In experiment I, a UPGMA dendrogram was constructed by using Mega 4.0 program to show phylogenic relationship among *Callistephus* accessions. In experiment II, China asters were grown in both winter and rainy seasons to evaluate the horticultural traits at two different growing seasons. In experiment III, China aster seeds were stored using different storage materials to find out the most suitable seed storage material for maintaining good seed quality.

5.1 Experiment I: Study on Phylogenic Relationship of China Aster

Variation of flower and stem colour depending on different seed sources was observed (Figure 3). This variation may be due to differences in the genetic makeup of cultivars. From the cluster analysis, Pyin-Oo-Lwin seed source was clearly distinguished from Yangon, Taungoo, Pyinmana seed sources (Figure 4). This suggested that Pyin-Oo-Lwin seed source had a remote relationship with Yangon, Taungoo and Pyinmana seed sources, whereas Yangon, Taungoo and Pyinmana seed sources had closer relationship with each other.

The analysis of variance showed significant differences among the accessions for qualitative traits (Table 2). High genetic variance was observed for most of the characters except the number of leaves per plant. These data suggested that differences in such characters were mainly due to different accessions which derived from different locations and had various qualitative and quantitative characters. Low coefficient of determination (R^2) value observed in number of leaves and plant height (0.65 and 0.75), implying that there were too much unknown factors for those characters.

5.2 Experiment II: Evaluation on Horticultural Traits of China Aster at Different Growing Seasons

According to the results, it was observed that the performance of China aster depended on the growing seasons. The plants were higher with more leaves in winter season than in rainy season (Table 3 and 4). This could be due to favourable conditions for plant growth of China aster in winter season. Similar trend of vigorous plant growth in winter season was also observed in China aster by Thuzar (2011). Among the seed sources, plant height responses were also different in response to the growing season. In winter season, Pyinmana seed source showed maximum plant height (54.45 cm) and Taungoo seed source showed minimum plant height (45.53 cm). However, these two seed sources showed opposite responses in rainy season. The plant height of Taungoo seed source was maximum (45.53 cm) while that of Pyinmana seed source was minimum (40.53 cm) in rainy season. These data described that plant height varied not only among the seed sources but also on the growing season that they were grown. Poornima et al. (2006) and Singh and Singh (2005) also observed the variation of plant height among the China aster varieties and growing season.

Similar trend was also observed in leaf production in winter season. Plants growing in winter season had higher number of leaves than those growing at the rainy season. However, significant variation of plant height among the seed sources was only observed in winter season while no significant variation of plant height was found in rainy season. Among the seed sources, leaf number production was also different in response to the growing season. In winter season, the highest number of leaves was observed in Yangon seed source (21.03) and the lowest in Taungoo seed source (18.99). Whereas in rainy season, the highest number of leaves was found in Pyinmana seed source (16.83) and the lowest in Yangon seed source (15.78). These data highlighted that the production of leaf depends not only on the growing season but also on seed sources. Production of more leaves in Yangon and Pyinmana seed sources could be due to vigorous growth which in turn facilitates better harvest of sunshine by the plant to produce more number of leaves.

Between the two growing seasons, number of branches was more in rainy season than in winter season (Table 5). These data highlighted that branching of China aster is influenced by the growing environment. Poornima et al. (2006) and

Baskaran et al. (2004) who observed that the difference in branch number among the cultivars was due to the influence of the genetic make-up of the cultivars in China aster and in chrysanthemum. In our result, we also noticed that there were some variations in the number of branches produced among the seed sources, but they are not significantly different. Therefore, variation in branch number in our experiment was only due to the influence of growing seasons.

No significant variation of canopy diameter among the seed source growing in different seasons suggested that the growing seasons did not influence on canopy diameter of China aster (Table 6). These results were contrary to the finding of Kulkarni and Reddy (2006) who observed different canopy diameter among the varieties of China aster.

Reproductive developments (days to floral bud initiation, days to first flower opening and days to 50 percent flowering) were quite different not only among the seed sources but also between the growing seasons (Table 7). Plants growing in rainy season showed earlier reproductive development than those growing in winter season. Among the seed sources, Taungoo seed source took minimum number of days to floral bud initiation, first flower opening and 50 percent flowering while Yangon seed source took maximum number in winter season significantly. This variation of reproductive developments among the seed sources and different growing season could be due to different daylength sensitivities and different genetic variation of China aster. Lin and Watson (1950) reported that China aster is the facultative long day plant and thus plants can also flower under short day condition and they accelerate flowering under long day condition. Moreover, Kumar and Yadav (2005) and Dilta et al. (2005) also observed that the variations of flower bud initiation and flower opening may be due to genetic trait.

Numbers of flowers recorded were more in rainy season than in winter season (Table 8). This could be due to higher number of branch production in rainy season than in winter season (Table 5). Gnyandev (2006) described that branch number contributes to flower bearing units which increases the number of flower in China aster. In winter season, Yangon seed source produced maximum numbers of flowers while it produces minimum number in rainy season. This could be due to the developments of branch number since higher branch number was produced in winter season for Yangon seed source. This finding was supported by Baskaran et al. (2004)

in chrysanthemum and Poornima et al. (2006) in China aster who observed similar results.

Flower diameter was bigger in winter than in rainy season. Variation of flower diameter observed at winter and rainy season could be due to different temperature regimes. Ben Hod et al. (1989) and Sharman et al. (1989) also described that the flower size decreases as temperature increases in chrysanthemum. Taungoo seed source showed maximum flower diameter (7.22cm) while Yangon seed source showed the minimum (6.94 cm) in winter season. In rainy season, maximum flower diameter (5.64 cm) was recorded in Pyinmana seed source and minimum in Taungoo seed source (5.16 cm). These data indicated that development of flower size varied depending on seed sources and also on growing seasons. This variation may be due to differences in the genetic make up of cultivars. Similar responses of flower size variations were reported by Poornima et al. (2006) in China aster, Singh and Singh (2005) in marigold and Dilta et al. (2005) in chrysanthemum.

5.3 Experiment III: Effect of Storage Materials on Seed Storage Quality of China Aster

The effects of storage materials on seed storage quality of China aster were studied. The storage quality of seed was evaluated by germination percentage, germination index and seedling vigour index (Table 9, 10 and 11). The results indicated that, in all seed sources, the seed quality of China aster reduces as the storage period increases. Naguib et al. (2011) observed that the longer storage period causes seed vigour and seed viability to decline and is manifested through the decrease in seedling vigour parameters. Similarly, the decrease in seedling vigour parameters with increase in storage period is reported by Bharathi (2002) in gaillardia, Doijode (1995) in onion, Sharma et al. (1998) and Hunje (2002) in chilli and Palaniswamy and Karivaratharaju (1991) in tomato.

At the end of six months seed storage, both Pyinmana and Taungoo seed sources maintained higher germination percentage, germination index and seedling vigour index than Yangon seed source suggesting that seed quality parameters varied depending on seed sources. Similar finding was observed in Delouche (1973) and Agrawal (1974) who found the variation of storage seed quality among the varieties, species and genera. Roberts (1973) and Delouche (1973) also reported that the different germination values among varieties of China aster seeds may be related to genetic make-up of varieties as storage potential is under genetic control and is heritable.

Among the seed storage materials, seed quality parameters were different throughout the storage period. Good seed quality was observed in seeds stored in aluminium foil and polythene bag compared to those stored in cloth and paper packet throughout the storage period. The results indicated the influence of storage materials on seed quality of China aster. Better seed quality in both aluminium foil and polythene bag could be due to the moisture impervious of storage materials that maintain seed viability for longer period. The superiority of aluminium foil as well as polythene bag over cloth bag and paper packet in maintaining viability was also reported by Bharathi (2002) in gaillardia, Hunje (2002) in chilli and Kumbar (1999) and Patil (2000) in chickpea. Similar decrease in seedling vigour parameters due to greater reduction of germination percentage and seedling length in seeds stored in moisture pervious containers has been reported by Bharathi (2002) in gaillardia, Doijode (1998), Sharma et al. (1998) and Hunje (2002) in chilli.

6. CONCLUSION

China aster has different flower and stem colour variations depending on seed sources. According to the study, four different colours of flower and two variations of stem colour were observed. YGN, TGO, PMA seed sources showed 43 to 50 % of dark pink flower, 5 to 10 % of red flower. Light pink flower (39 to 47%) was found in all seed sources and about 22 % of white flower was observed in only Pyin-Oo-Lwin seed source. Two different stem colours were resulted: 1 to about 86 % of green stem and 14 to about 99 % of red stem.

Based on horticultural traits, *Callistephus* accessions clustered into three main groups in UPGMA (unweighted pair-group method) phylogram. Group I and II included POL seed source, group III contained YGN, TGO, PMA seed sources. POL seed source had remote relationship with YGN, TGO and PMA seed sources which are closely related one another.

Growing seasons had a great influence on horticultural traits of China aster. Number of leaves and plant height were higher in winter season than rainy season. However, number of days to floral bud initiation, first flower opening date and 50% flowering date were later in winter than in rainy season. The plant produced more number of flowers but smaller flower diameter with shorter stem in rainy season than in winter season. This study highlighted that winter is more suitable condition for China aster production compared to rainy season to produce longer stem and big flowers.

Storage materials influenced seed storage quality of China aster. As storage duration increased, germination percentage, germination index and seedling vigour index decreased. Greater germination percentage was observed in aluminum foil bag (85.17%), polythene bag (84.17%) and bottle (80.50%) in comparison with paper (64.50%) and cloth bag (60.67%) after 6 months of seed storage. Thus, aluminium foil bag, polythene bag and bottle can be used for longer seed storage of China aster. Moreover, the influence of genetic make-up is also a factor in varying the seed storage quality of China aster.

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