Performance of Medicinal and Aromatic Chamomile (	extit{Matricaria chamomilla} L.) under Different Planting, Manure cum Fertilizer Regimes in Kathmandu Valley

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Abstract: New and old genotypes of German chamomile (\textit{Matricaria chamomilla} Linn.) were experimented under different planting methods, manure and fertilizer combinations first time in Kathmandu valley. The researches aimed at evaluating genotypes performance, identifying suitable planting method and optimum combination of manures and fertilizers. The germplasm evaluation experiment was conducted at the National Agriculture Research Institute (NARI) field, Khumaltar during January-May. Planting method trial was laid out in randomized complete block and manure cum fertilizer trial was in Latin square design (LSD). The results showed good performance of chamomile growth, development and oil content. Major agronomic traits had average figures in all experiments comparable to chamomile growing areas. Most data differed significantly and at par. New genotype produced relatively higher number of branches, leaves and flower heads maintaining more plant density. Growth was higher in row sown and transplanted plots, row sowing found more beneficial. Transplanted plots delayed maturity. Transplanted (0.95\%) and broadcasted (0.80\%) chamomile gave higher oil percentage, no difference found between genotypes. Significantly ($p < 0.05$) higher and at par branch numbers, flower heads, biomass yield, plant height were recorded in the treatments with higher rate of farm yard manure (FYM) 20 t/ha followed by combined application of NPK 60:40:20 kg/ha plus manure 10 t/ha. Oil content was the highest (0.95\%) in FYM (20 t/ha) applied plots followed by combined fertilization (0.80\%). Despite inferior to treatment N:P:K 60:40:20 kg/ha only to enhance growth and oil production, other results suggested suitable technology and successful cultivation of chamomile in valley conditions are recommended.

Key words: German chamomile, performance, planting method, manure & fertilization, cultivation, Kathmandu valley.

1. Introduction

1.1 General Introduction

Chamomile is one of the most important ancient medicinal and aromatic plant (MAP) species for the mankind. The name chamomile is derived from two Greek words: \textit{Khamai} meaning “on the ground” and \textit{melon} meaning “apple”, the flowers having apple-like aroma [1]. This herb has been used since the time of Hippocrates, the father of medicine in 500 before Common Era (BCE) [2]. It is commonly known as chamomile, German chamomile, Hungarian chamomile, true chamomile, wild chamomile, flos chamomillae, blue chamomile, sweet false chamomile, \textit{Matricaria} flowers, pinheads, and Babuna in various parts of the world [3]. In Nepal, it is called Chamomayil phool, Tarephool, Daminipool and Chareswan [4]. Binomial scientific name of German chamomile is \textit{Matricaria chamomilla} Linn. of the family Asteraceae (formerly Compositae). It is native to southern and eastern Europe, originated in Europe and West Asia [5] in medieval. Chamomile was brought into cultivation during the Neolithic period approximately 9,000 to 7,000 BC. Its production and uses have a long history for medical and cosmetic purposes. Since ancient times, its dry flowers were highly valued and used by the Egyptians, Romans and Greeks for its medicinal properties. They used to cultivate [5] and use the flowers to treat erythema and xerosis caused by dry
weather. Now cultivation and use has spread to most countries in all continents. The chief producers are Argentina, Egypt, Germany, France, Italy, Turkey, Greece, Bulgaria, Yugoslavia, Hungary, Slovakia, and Australia. Hungary is a main producer. In 1998, the world production of chamomile blue was estimated to be 1,000 t of dried flowers from large-scale farming [6]. In 2003, about 50,000 acres of land was under chamomile cultivation worldwide. In India, chamomile was introduced during the Mughal period, about 300 years ago in Punjab, grown mainly in north-west states [7]. The Roman chamomile (Chamaemelum nobile (L.)) also looks similar to the German chamomile, and belongs to the same family. However, there are morphological differences in the flowers, and the chemical constituents of essential oil (EO) are different [8]. Chamomile is an annual herb of 40-80 cm high [9]. It gives rise to white flowers and changes into yellowish while maturity. The flower heads contain EO having broad-spectrum values. Chamomile is now widely used, widely cultivated medicinal crop for flower and oil throughout the world [10].

Nepal is rich in MAPs where the Department of Plant Resources under Ministry of Forest and Soil Conservation (MoFSC) has listed 701 species out of 7,000 species of vascular plants [11]. The database of Nepal’s medicinal and aromatic plants (MAPDON), “Jadibuti” (in Nepali) encompasses over 1,624 species [12] across the country. Most of them are endemic and indigenous. Over 150 species are traded from Nepal [9, 13]. They are used in Ayurvedic, Homeopathic and Tibetan systems. However chamomile is exotic for Nepal, introduced after 1980. It has adapted and thrives well in Tarai plain from east to west of Lumbini, Buddha’s birthplace [14]. Exact production and cultivation area is not available due to lack of survey. It can be estimated from the yearly export volume of oil, 1.5 to 2 t and the average production of oil 6 kg/ha. The the area will be 250-333 ha or more. Nepalese farmers have been losing agro-crops caused by wild animals, particularly around the wildlife reserves and national parks. Since chamomile is non-palatable to wild animals, such loss can be avoided.

Export of EOs from Nepal is small [15], rising after 2010 by 11% (USD974 to 1,626 thousand), by volume it rose 21-37 t. Chamomile oil is produced up to 2,000 kg. Price of oil in recent years fluctuated from 40,000 to 58,000 NPR/kg [16]. The oil is chiefly exported to Germany, other European countries, and to India. USA is the largest destination by value followed by France, Belgium, Germany, UK and Canada. As the supply of Nepal’s oil is low, increasing production by expanding area is felt to be a best way to raise export and earn foreign currency. Nepal’s German chamomile oil has greater anti-inflammatory properties than Roman chamomile because of higher percentage of chamazulene [4]. Nepal’s chamomile oil is preferred in the international market [16]. Organoleptic properties of oil are: viscous, dark greenish blue, intensely sweet aroma with fresh-fruity undertone. The worldwide demand and consumption of chamomile is high after 2010 and ever increasing, mainly in South American countries, Chile. As the demand for chamomile-based products is increasing, India and Tasmania [17] have planned to increase cultivation.

1.2 Botanical Characteristics

German chamomile (Matricaria chamomilla Linn.) belongs to the Asteraceae (Compositae) family. It is an annual herbaceous plant with short roots. Plant is multi-branched, long and narrow compound leaves, leaflets slightly hairy with minute lobes, petiole externally covered by green colored leaves (Figs. 1a-1c). Flower heads separate, diameter 10-30 mm, heterogamous. Tubular florets are golden yellow with 5 teeth, 1.5-2.5 mm ending in a glandulous tube, sepal white and inner petals yellow. Smell of flower sweet, continued in dry flower. Seed is small, light and elongated. Roots are thin, spindle-shaped. Stem is branched, erect, heavily ramified. The number of flowers per plant is 11-27 which are white, 6-11 mm long, 3.5 mm wide, are
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Fig. 1  Photos of German chamomile (*Matricaria chamomilla* L.): (a) local genotype of Tarai, (b) general full plant and (c) new genotype from Europe grown in trial.

arranged concentrically. The receptacle 6-8 mm wide, flat and conical, becomes cone-shaped later, hollow—the latter being a very important distinctive characteristic of *Matricaria*. Fruit is yellowish and brown ached [7]. Flower radius is 1.3 cm to 2.5 cm. Plant grows to a height of 10-90 cm depending upon the growing environments.

1.3 Actions and Uses of Chamomile

1.3.1 Actions

Chamomile is known to be anti-inflammatory, anti-spasmodic, anti-bacterial, and anti-septic [18, 19]. There are hundreds of actions and uses of chamomile flower and oil. It is carminative, analgesic, vulnerary, aromatic, bitter, diaphoretic, emmenagogue, nerve, sedative, tonic, anti-allergenic, fungicidal, hepatic, nerve sedative, and stomachic [4, 20, 21]. The EO and flower extracts contain more than 120 secondary metabolites, such as chamazulene, apigenin, luteolin etc., many of which are pharmacologically active. Farnesene, bisabolone oxide, butylated hydroxytoluene, cadinene and caryophyllene are also active chemical constituents [16] and used in flavor, fragrances and medicines. The extracts and oil are the ingredients of several folk and traditional herbal remedies, complementary and alternative systems of medicine, such as Homeopathy and Unani.

1.3.2 Uses

The use of chamomile is large and immense. Its flower and oil is extensively used in cosmetics, perfumery and flavoring food materials, chocolates, drinks etc. It is used to prepare high class perfumes, soaps, shampoo, detergents, hair and bath products. It also has high medicinal value [4, 20]. Used for curing fever in the past, now it is used as gargle for sore throats and sore eyes. Oil is used for massaging muscles and joints to reduce pain. It also helps reduce inflammation and dark shadows under the eye. Oils are also used in spa for relaxation which reduces anxiety and insomnia. It is added in baby oils for strengthening bones [14]. According to Himalayan doctor, chamomile is good for indigestion and relaxing mind. It is used in pharmaceutical, antiseptic, ointments and tonic preparations. It is non-toxic, non-irritant, and safe for use. Inhalation over a steam bath will speed recovery from nasal catarrh. It is useful in eczema and wound healing and reduces swelling. It softens and whitens sun or wind-damaged skin. Analgesic and disinfectant qualities treat diaper rash and soothe toothache. The flower compounds have shown anti-tumor activity [4]. Flower decoction conditions and lightens fair hair. Detailed uses of chamomile against diseases/ailments listed in Ref. [21] are: alcohol withdrawal, anorexia nervosa, anxiety, asthma, athlete’s foot, binge eating disorder, boils, bruxism, burns, canker sores, chicken pox, chills, colic, conjunctivitis, constipation, corns, cradle cap, cuts and scratches, dermatitis, diarrhea, diverticulitis, dry mouth, eczema, epilepsy, fibromyalgia, fractures, fungal infections, gas, gastritis, heartburn, holistic dentistry, hypertension, indigestion, inflammatory bowel disease, insomnia, juvenile rheumatoid arthritis,
knee pain, low back pain, measles, Ménière’s disease, menstrual problems, nausea, osteoarthritis, ear disorder, ovarian cysts, psoriasis, radiation injury, rashes, rheumatic fever, scarlet fever, stomach ache, teething problems. Chamomile is used in traditional, Homeopathy and Unani systems of medicine. Homeopathy works on the combined principles of a group of symptoms present in a disease and a group of symptoms caused by the effect of a drug on a healthy human [21]. The principle says “let likes be cured by likes” [3]. The Unani system originated in Greece and developed by the Arabs works under the principle of “disease is a natural process and the symptoms are the reactions of the body to the disease” [22]. It is widely practiced in the Arabian and in south Asian countries.

1.4 Chamomile Cultivation Experience in Nepal

In Nepal, different organizations have been involved in chamomile cultivation, processing, oil extraction and marketing later years [23]. The Herbs Production & Processing Company Ltd. [16], an undertaking of Nepal government and a pioneer of chamomile cultivation in Nepal had introduced it in 1990. It is already adapted, thrives well in the Tarai region. The Herbs Production and Processing Company Ltd. (HPPCL), has long experience in cultivating chamomile in its farms in Tarai areas: Tamagadhi (Bara district), Tarahara and Belbari (Sunsari and Morang districts respectively) and in Tikapur (Kailali district). Hundreds of farmers residing the vicinity of the farms have been involved in cultivating chamomile through HPPCL support and mobilization. Farmers-produced chamomile is also distilled and oil extracted in the company’s plant on rent. Total production of oil from the farms and on-farms in fiscal 2018/19 was 860 kg, of which Tamagadhi alone had 624 kg [16]. Future plan is over 1,000 kg per annum. Current price of oil is NPR50,000 (USD440). Chamomile is grown through seeding; seeds are mixed with sand or ash in 1:30 ratio and sown 30-40 cm apart in rows. Main sowing time is November-December. Plant grows up to 90 cm tall. Harvesting is done cutting one third plants with flowers from the tip and second cutting is done one month after first harvest. Plants are wilted and distilled to extract oil.

A chamomile project [24] was launched in the mid-and far-western Tarai. Its experience is: flowering period: Magh (Jan) to Chait (April), plant heights 60-90 cm, average fresh yield of flower heads 300 kg per Ropani (500 m$^2$) from which 7-10 kg seed is produced. Flowers can be harvested March onwards twice to thrice up to May if moisture is available. Dark blue color of oil is a good quality. It possesses bactericide and fungicide property. As disease and pests are not problem for chamomile, except aphid, pesticides are not applied. Chamomile is grown even without chemical fertilizers [20]. An advantage to Nepalese growers is that chamomile plant is not eaten by wild and stray animals. Barakoti [9] and Shrestha [14] noted that chamomile can grow up to 1,800 masl but cultivation in the hills and valleys is lacking and not explored. Even in Tarai, its farming is limited in few districts. This species is still new to most Nepalese.

Chamomile farming has shown prospects in Bara district [25]. When farmers realized the potential of chamomile, they started to cultivate it. As wild animals have been damaging food crops, chamomile was found safe to grow in the surroundings of wildlife’s reserves and national parks. Mr. I. S. Lama started to grow three years ago in 0.5 ha; he urged if seeds and technical assistance will be provided by Natural Resources Industries Pvt Ltd, chamomile farming would not be difficult. As per Technical Advisor (Jaiswal): out of 101 ha of land, 81 ha is covered by chamomile only. Over 200 farmers have been undertaking this venture.

Chamomile has great potential for Nepal [14] because of high value compared to food crops and high demand from foreign markets. The potentiality could be explored if the government endorses conducive
The research project has put the following objectives:
- To evaluate the performance and compare commercially grown local and new genotypes of German chamomile;
- To identify suitable planting method among rowsowing, broadcasting and transplanting methods;
- To determine biomass yield and EO content in flower of both genotypes;
- To determine appropriate rate of manure and fertilizer along with combined dose in valley condition;
- To recommend and disseminate identified findings/technologies to the growers.

2. Materials and Methods

The field experiments were conducted with German chamomile in National Agriculture Research Institute (NARI) premise Khumaltar, Kathmandu during the winter period from November to May in three sites. Details of research material, location, experimental design, planting method, analysis of soil, oil content and environmental factors are provided below.

2.1 Research Material/Germplasm

Two genotypes/varieties of chamomile viz. localized German chamomile (LGC) and new German chamomile (NGC) were planned to test in the experiments for their performances (Fig. 1). The typical old genotype of German chamomile grown more than a decade in the Tarai of Nepal is shown in Fig. 1a. It has pointed long compound leaf (Fig. 1b), long inter-node, white flower petals and yellow flower head. The newly brought genotype of German chamomile seeds from Europe grown in the trial plot (Fig. 1c) shows little bit bigger flower and more leaves in the plant. It might be due to the plant part of the photography taken. Due to the same species there is not much variation in the morphology. Other characteristics are not made available by the supplier.

Seeds of LGC were made available by an agriculture officer of HPPCL from the company’s
farm in Tarai and seeds of NGC were provided by a project officer of iDE-Nepal. Manure cum fertilizer trial used the NGC seeds only.

2.2 Location of Research/Site

The proposed on-station experiments were carried out in the premises of the NARI, Khumaltar, Lalitpur district, Kathmandu valley. Trials were conducted in three locations: variety cum planting method trial nearby NARI building, fertilizer trial one in the research field of Plant Pathology Division and another in the research field of National Genetic Resources Bank, Khumaltar by the side of Integrated Mountain Development (ICIMOD) building.

2.3 Design of Experiment

There were two designs of the conducted field experiments for chamomile: randomized complete block design (RCBD) and Latin square design (LSD). RCBD was employed for variety cum planting method trial (Table 1) and LSD (Table 2) was chosen for manure cum fertilizer trial. According to this design equal numbers of treatments (4) and replications (4) were laid out. Details of layout and randomization of treatments are provided in Tables 1 and 2.

2.4 Planting Method Tested

Three different methods of planting were tested as planned for observing performance of chamomile. Those were: broadcasting, line sowing and transplanting. Plot size was 3 m \(\times\) 3.5 m =10.5 m\(^2\) which consisted of 6 rows with row to row distance/spacing making 50 cm. Seeding was done in the manually prepared land on December 9th and transplanting at the end of December. Sowing and transplanting were done continuously in rows. Three weeks old seedlings produced in a side of plot were transplanted. Broadcasting of seed was done evenly on the whole plot and slightly stirred the soil. Seed rate was 1 g/plot. Harvesting was done twice: first harvesting continued in April (first and last week) and second harvesting in April (last week) and May (last week trans. plots).

2.5 Manure and Fertilizer Applied

The mixed manure of pigs and cows as farm yard manure (FYM) from National Animal Science Research Institute (NASRI), Khumaltar was used in the trial. The air dried manure was weighed and applied 15 t/ha in all plots of the variety cum planting method experiment. The doses of FYM in the manure cum fertilizer trials were 12.5 kg/plot for 10 t/ha and 25 kg/plot for 20 t/ha which were applied after tillage and leveling the plots in the seeding rows. A flat rate of N:P:K 60:40:20 kg/ha respectively recommended for most crops by Soil Science Division (SSD), Khumaltar was applied. The fertilizers were diammonium phosphate (DAP) for phosphorus (P\(_2\)O\(_5\)), urea for nitrogen (N) and muriate of potash (MoP) for potassium (K\(_2\)O). Nutrients content in DAP was 20% N and 20% P\(_2\)O\(_5\), in urea 60% N and in MoP 60% K\(_2\)O. The calculated doses applied 200, 43 and 33 g/plot respectively. The experimental plots were ploughed by tractor and prepared manually.

The manure cum fertilizer trial was conducted alternately in two locations at Khumaltar. Its layout

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and randomization done in LSD is shown in Table 2. It was employed in both locations. Plot size was 5 m × 2.5 m = 12.5 m² with 6 rows, and row to row distance/spacing was 40 cm. There was continuous seeding in rows. Sowing was done in first week of January. Seeds were mixed with rice bran ashes at 1:20 ratio.

2.6 Moisture Content Analysis

Chamomile moisture was determined in Seed Science and Technology Division Lab of NARI, Khumaltar. Fresh composite samples of chamomile plants were weighed 200 g/plot. Samples of flowers and heads were taken 100 g/plot. They were put in the dryer and heated at 65 °C for 90 h. After getting out from the dryer the samples were weighed and the differences calculated. The moisture percent of variety cum planting method trial varied from 57.9% to 84.7%. Most samples had 78%-82% moisture. Samples of fertilizer trials had 77%-80% moisture.

2.7 Data Monitoring and Recording

The experimental data in the field were recorded following standard methods of biometrics. Growth monitoring was started when the plants attained the flowering stage. Plant heights were measured and number of branches, number of leaves, number of flowers, and number of flower heads per plant were counted at peak flowering time prior to first harvesting in all trial plots. Data recording was done in randomly selected 10 plants for each trait from 3 inner rows at 3 places continuously visualizing the normal growth and average heights. Then the mean data per plant were calculated. Samples for lab analysis were also collected in this way. Plant stands were counted after first harvesting in the observation rows and estimated. It has been difficult to count the fully mature flower heads before second harvest and so partially mature flowers were also added.

2.8 Analysis of Oil Content

Chamomile oil percent was determined in the Food Technology Division (FTD) Lab of NARI, Khumaltar through distillation method. Composite samples of flower heads were collected 50 g from each replication of a treatment and air dried. Those samples were provided to the lab for moister content analysis. The dried flower heads were weighed 10 g per sample and kept in round bottom flask. Then water was added in the flask bottom to dip so that the flower heads may not be over-dried/flamed. Then samples were heated in the electrical heater for 2 h at 70-75 °C. Then reading was taken in the graded Clevenger trap. The figures were converted into percentage, such as if reading level was 0.07, 0.07/10 × 100 = 0.7%. Thus oil content was analyzed.

2.9 Analysis of Monitored Data

The recorded data from the experiments were subjected to statistical analysis. The analysis of variances (ANOVA) was performed using the standard method and tools. One-way ANOVA has been used [27] for the analysis of genotype cum planting method (GPM) trial data. And Orthogonal LSD was used [28] to analyze data obtained from manure cum fertilizer trials.

2.10 Climatic Condition of the Site during Experimentation

The chamomile planting starts in winter (Nov.) and ends in summer (May), October to April is drier
season. Precipitation of this period is occasional, very low rain and dew (5%-10%). Relative humidity varies 10%-100% and air temperatures 0-20 °C during Dec.-Feb. and 10-32 °C in March and April when wind velocity reaches up to 44 km/h few days. Rise in temperature and wind after March may cause quick drying of soil and low humidity. Uneven distribution of rainfall is the typical characteristic of Nepal’s climate. More than 80% of the precipitation is rainfall during summer-rainy season of May-Sep., 30%-60% in Jun-Sep. only. Therefore winter crops may suffer if there is no irrigation facility. In the experimented site, first year was moisture deficit for plant. Therefore the crop was watered with watering can in the beginning (Figs. 2 and 3) and through pumping set at flowering stage. The second year was relatively normal for the crops. Even though, irrigation was done thrice. Thus the unfavorable climate condition was overcome.

3. Results and Discussion

3.1 Results of GPM Experiment

The GPM experiment was aimed to compare local and new genotypes of German chamomile under different planting environments. The results have shown encouraging performance, revealing good growth and development in the experiment. The major agronomical traits of growth and development, such as plant height, number of branches, number of flower heads, plant stands, oil and biomass yields were monitored. The mean data varied significantly (p < 0.05) and non-significantly between the treatments. The new German genotype had higher plant, more number of branches, leaves and flower heads than old genotype of Tarai. Growth was higher in row sown and transplanted plots and row sowing was more beneficial than other method. The EO content had no difference between genotypes but transplanted one had higher oil percent (0.95%) than broadcasted one (0.80%) which had higher plant stands. The result of traits are described in Tables 3 and 4.

3.2 Response of Chamomile Genotype to Planting Method/Density

Direct sowing of seeds usually results in poor germination, hence transplanting is followed. Mortality of the seedlings is almost negligible in transplanting. A study [29] revealed that transplanting was better than direct sowing, and the best time of transplanting is Oct. for higher yields. Plant density had significant effect on the yield and harvest index. The highest yields of dried flower (1,241 kg/ha), EO (8.06 kg/ha), seed (765 kg/ha) and biomass (2,716 kg/ha) were obtained from 10 cm intra-row distance. At 25 cm distance, there was the lowest flower yield (765 kg/ha), oil (4.92 kg/ha) and seed (574 kg/ha). When the spacing narrowed, seed yield increased. On contrary to it, results in Ref. [30] showed maximum yield (1,803 kg/ha) in row spacing of 55 cm. It suggests that sowing of chamomile at 30-50 cm distance may need to revise for higher yields. To confirm this, a row spacing trial is required to study.
The performance of the two genotypes of German chamomile was evaluated through the measurement of its growth attributes. There was moisture deficient to the emerged plants in the trial and so watering was done (Fig. 2). Then the plants showed good growth as observed by the researcher (Fig. 3). The adjoining vacant plots are for transplanting soon. The agronomic traits observed, and data recorded during its growing period are summarized in Table 5 below.

Plant stands of chamomile counted after first harvesting are presented in Table 3. The stands were found to be highly varied based on genotypes and planting methods (330-636 ths./ha). The highest stands (> 622 ths./ha) were in the seed broadcasted plots and the lowest stands (351 ths./ha) in the transplanted plots. Row sowing had intermediate one (497 ths./ha). Seed rate being the same quantity (1 g/plot), the low stands in row sowing would be due to covering of few seeds by soil in the furrow. Transplanted seedlings had obviously low numbers from the beginning. The means of improved genotype had higher stands by 27 thousand than local one and the data were significant ($p < 0.05$).

Plant heights ranged 46.6 to 62 cm (Table 3) and their means varied nearly significantly. The grand mean height was 56.9 cm matching to the heights grown in the Tarai. Higher trends of growth in new chamomile were seen, however the reason of lower heights in transplanted plants was not clear. When the plants attained 10-15 cm high in other treatment plots, the vacant (Fig. 3) transplanting plots were began planting.

Number of branches per plant recorded (Table 3) before first harvesting, significantly ($p < 0.05$) varied between 9.7 (local genotype broadcasting) and 17.1 (improved genotype transplanting). Grand mean was 12.6 per plant. The means of improved genotype had higher numbers and the transplanted plants bore the highest branches per plant. It may be due to the more area-spacing for less number of plants as these treatments had the lowest density.

Number of leaves per plant followed similar trend as the number of branches in the experiment (Table 3). There were minimum differences between the...
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treatments (11.1-13.8) and so the numbers gave non-significant results. It should be noted that the lower leaves from the plants had fell down at the time of counting.

Number of flower heads per plant counted at both harvesting time in the chamomile plant varied from 22.4 (local genotype broadcasted) to 27.7 (improved genotype row sown). The means (Table 3) were not significant, however flower heads were higher in row sowing (26.4) followed by transplanting (25.8) treatments in the experiment.

Maturity days to harvesting: the growing period of chamomile was estimated from planting to maturity days i.e. first and second harvesting (Table 4). First harvesting was done on 144 d in all treatments, except transplanted plots (167 d) where the mean was 151 d in Kathmandu valley. It was identified that transplanted chamomile delays 3 weeks to mature the flowers. Mean period to second harvesting was 175 d, with 166 d in row sowing and in broadcasting and 194 d in transplanted plots. The data were significant (*p* < 0.05) and at par. Vigorously growing plants before flowering (Fig. 4) and of flowering stage (Fig. 5) are shown.

Yield of plant biomass: the air dried biomass of chamomile plants (Table 4) varied from 2,797 kg/ha (local genotype transplanted) to 4,284 kg/ha (improved genotype row sown) where the grand mean was 3,492 kg/ha. The data significantly differed between the treatments and had also definite trend. Improved genotype had higher biomass (3,607 kg/ha) than local genotype (3,377 kg/ha). The highest biomass yield was produced in the row sowing (4,199 kg/ha) and the lowest yield in transplanted plot (2,963 kg/ha) broadcasting being intermediate (3,313 kg/ha). Fig. 6 shows the vigorously growing chamomile in the trial plot before flowering, and Fig. 7 shows maturing flower heads before first harvesting.

Yield of flower heads: of the grand mean (1,325 kg/ha) flower heads were the lowest (1,055 kg/ha) in local genotype broadcasting and the highest (1,586 kg/ha) was in row sowing of improved genotype, the difference being 531 kg/ha (Table 4). The treatment data significantly (*p* < 0.05) differed between the means. Improved genotype over-yielded by 169 kg/ha than local genotype. It was confirmed that row sowing was superior (1,533 kg/ha) to transplanting (1,306 kg/ha) and the later was superior to broadcasting (1,139 kg/ha) method of sowing in flower head yield. The view of first harvesting is presented in Fig. 7.
Oil content in flower head was found above average in the experiment as compared to the commercial plantation fields. The analysis carried out in the FTD laboratory at Khusmaltar showed 0.7% to 1.0% (Table 4) of EO, when the grand mean was 0.86%. There was no any relation in oil content based on the germplasm source and planting methods and the means were nearly significant. However the oil content as a major yield or produce, the result showed economically viable to cultivate chamomile in the Kathmandu valley.

The statistical analysis of the collected data of two genotypes of German chamomile was performed employing one-way ANOVA for F-test. Their p-values varied from 0.009 (biomass yields) to 0.332 (weight of flower heads), 95% critical values were in range of most traits, statistic F equals 1.39-3.05, 95% coefficient of variation (CV) statistic F, effect size f was large (0.53-1.23), test power was low (0.097) and the standard error ranged between 0.453 (biomass yield) and 1.187 (plant height). Those were comparable with the results of other experiments as significant and non-significant.

3.3 Role of Organic and Chemical Fertilizers on Plant Growth and Yield

Plant nutrition is one of the most important factors that increase plant production. Researchers [31-34] reported about the benefit of organic and chemical fertilizers for chamomile. Intensive cultivation of agro-crops has led to a rapid decline in organic matter and nutrient levels in soils besides affecting the physical properties. The organic materials influence agricultural sustainability improving physical, chemical and biological properties of soils [35]. But Saber et al. [32] observed non-significant effect of organic fertilizers on soil pH and organic matter. The optimum amount of NPK for chamomile on that soil was 70 kg N, 35 kg of P and K each [32]. Compost overcame the chemical fertilizers, improved growth and weights of flower heads and EO content [33]. The positive impact is due to the improvement of biological activities in soil and the absorption of mineral elements. Therefore response of organic manure (FYM) together with chemical fertilizer solely and in combination was tested in the experiment. The results of the effects of manure and fertilizer are summarized below.

3.4 Response of Organic Fertilizers to Soil and Chamomile

Organic fertilizers revealed significantly higher yields of chamomile flower but did not affect soil pH, organic matter, P and K. Compost treatments improved growth of flower heads, increased weights and content of EOs compared to chemical fertilizers [33]. Organic manures improve soil physical and chemical properties important for plant growth. The positive effect is due to the improvement of biological activities in soil and absorption of mineral elements. Researchers [36, 37] found positive and significantly stimulatory effects of vermicompost on growth, increased height, flower yield, EO and chamazulene content of chamomile. ANOVA showed significant effect on EO varying between 0.34% and 0.49% from control and 20 t/ha respectively. The results showed the highest plant height, fresh and dry flower yields (3,336 and 654 kg/ha respectively) and oil content by using 20 t/ha vermicompost. Application of 15-25 t/ha of FYM proved beneficial [29].
3.5 Response of Chemical Fertilizers to Soil and Chamomile

Karami [38] reported the effects of nitrogen (N), phosphorous (P) and potassium (K) on yield, EO content and composition of chamomile (C. recutita). Results indicated that various treatments of fertilizers affected oil yields and EO components. N plays an important role in synthesis of the plant constituents. P plays an important role in metabolic processes, enhances seed germination and early growth, stimulates blooming, bud set, seed formation and hastens maturity. High P rates decreased EO yield. K plays an important role in growth, yield and quality of crops [39, 40]. Application of 50 kg/ha P₂O₅ significantly increased the total dry matter and EO yield in mint (Mentha longifolia). Inorganic NPK fertilization increased the vegetative growth and EO content of some medicinal Apiaceae plants.

The number of flower heads and the yield significantly increased due to additional levels of N in the genotypes. The effect of N was very marked on the fresh flowers and oil yield, whereas P and K had negligible effect. Nitrogen in the form of ammonium sulfate at 40 kg/ha significantly increased fresh flower yield, but the oil content decreased 0.64%-0.59%. The contribution of N to the EO increment was 25% to 42% in genotypes. There was no change in the composition of EO based on N levels. Research data on the effect of N on growth, yield, and oil content in chamomile are contradictory [41]. Viewing the positive effects and need of organic and chemical fertilizers for chamomile present research was planned to study sole organic, sole chemical and the combination of both estimating average rate for normal growth and oil content practically. The results found not much varied significantly between the treatments.

3.6 Results of Manure cum Fertilizer Trial on Chamomile, Year 1

Table 5 presents agronomic traits (plant height, branch, leaf and flower head number) of chamomile. Higher number of branches and flowers, increased height and biomass yield were recorded in the treatments with higher rate of FYM (20 t/ha) followed by combined application of NPK (60:40:20 kg/ha) and manure (10 t/ha). The means of different traits differed significantly (p < 0.05), at par and non-significantly between the treatments, rows and columns. Chemical fertilizers (N:P:K 60:40:20 kg/ha) only found inferior to enhance growth and oil percent. Oil content was the highest in manure applied (20 t/ha) followed by combined fertilization (0.80%) treatment. Low rate of FYM (10 t/ha) increased oil (up to 0.7%). The results indicated successful cultivation of chamomile with the tested rate of manure and fertilizer. The layout and furrow marking of the manure cum fertilizer trial (Fig. 8) and the views of the flowering stage of chamomile (Fig. 9) in the same trial plots are presented.

The effects of FYM and chemical fertilizers on the agronomic traits of chamomile such as plant height, branch and leaf number and flower heads are presented in Table 5. The heights ranged 46.6-52.4 cm and did not vary significantly between the treatments. There was little response of chamomile to different doses of manure and fertilizers including the combined doses. Branch number also responded similarly. There was no marked variation between the treatments (10-12 branches per plant). Leaf number also had no much difference (10.9-12.3), followed the same trends as Fig. 8  Layout/furrow making of fertilizer trial.
The weight of 100 flower heads ranged 10.8-12.5 g per plant. The data were found not to follow the trend based on the dose of manure and fertilizer. Yield of flower head was found to be the lowest (2,066 kg/ha) in the treatment of NPK 60:40:20 and the highest (2,463 kg/ha) in FYM 20 t/ha. The data were significant. Fresh biomass yield of chamomile was converted into hectare. The yield data were found to be significantly ($p < 0.05$) varied (7,526-7,628 kg/ha) between higher and lower doses of manure and fertilizer. The increasing and decreasing trend was same as in biomass yield. Plant stands were finally counted at first harvesting time. There was no definite trend based on the doses of manure and fertilizer. However, the chemical NPK had negative impact on the decreased stands (383.3 ths./ha) as compared to manure alone and in combination (528.5 ths./ha).

**Table 5** Effects of manures and fertilizers on agronomic traits of new German chamomile at Plant Protection Division (PPD) field, Khumaltar, Kathmandu valley, year 1.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height, cm</th>
<th>Branch number</th>
<th>Leaf number</th>
<th>Flower head number</th>
</tr>
</thead>
<tbody>
<tr>
<td>FYM 10 t/ha</td>
<td>50.3</td>
<td>11.0</td>
<td>12.3</td>
<td>22.0</td>
</tr>
<tr>
<td>FYM 20 t/ha</td>
<td>52.4</td>
<td>11.5</td>
<td>12.2</td>
<td>21.2</td>
</tr>
<tr>
<td>N:P:K 60:40:20 kg/ha</td>
<td>46.6</td>
<td>10.0</td>
<td>10.9</td>
<td>17.8</td>
</tr>
<tr>
<td>N:P:K 60:40:20 kg &amp; FYM 10 t/ha</td>
<td>49.3</td>
<td>11.9</td>
<td>11.2</td>
<td>22.5</td>
</tr>
<tr>
<td>Mean</td>
<td>49.7</td>
<td>11.1</td>
<td>11.7</td>
<td>20.8</td>
</tr>
</tbody>
</table>

A selected normal grown chamomile plant of the experiment had 50 cm height, 12 branches, 13 leaves and 23 flower buds plus heads.

Fig. 9 Flowering view in a fertilizer trial.

height and branch. Flower heads were 17.8 (NPK only) and 22.5 (NPK plus FYM) in the trial and varied significantly ($p < 0.05$) but did not follow definite trend. The views of flowering chamomile in the trial plots are presented in Fig. 10.

The weight and yield of flower heads and plant biomass, stands and oil content are presented in Table 6.

Fig. 10 Observing flowering of new German chamomile in (a) planting methods and (b) fertilizer trial.
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Table 6  Effects of manures and fertilizers on agronomic traits of new German chamomile at PPD field, Khumaltar, Kathmandu valley, year 1.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Weight of 100 flower heads, g</th>
<th>Yield of fresh flower heads, kg/ha</th>
<th>Yield of fresh biomass, kg/ha</th>
<th>Plant stand, ths./ha</th>
<th>Oil content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>FYM 10 t/ha</td>
<td>12.5</td>
<td>2.266</td>
<td>6.814</td>
<td>528.5</td>
<td>0.52</td>
</tr>
<tr>
<td>FYM 20 t/ha</td>
<td>11.5</td>
<td>2.463</td>
<td>7.526</td>
<td>427.8</td>
<td>0.65</td>
</tr>
<tr>
<td>N:P:K 60:40:20 kg/ha</td>
<td>10.8</td>
<td>2.066</td>
<td>6.344</td>
<td>383.3</td>
<td>0.53</td>
</tr>
<tr>
<td>N:P:K 60:40:20 kg &amp; FYM 10 t/ha</td>
<td>12.3</td>
<td>2.133</td>
<td>7.628</td>
<td>434.0</td>
<td>0.48</td>
</tr>
<tr>
<td>Mean</td>
<td>11.8</td>
<td>2.232</td>
<td>7.078</td>
<td>433.4</td>
<td>0.545</td>
</tr>
</tbody>
</table>

Table 7  ANOVA summary of manure cum fertilizer trial data analyzed by orthogonal 4 × 4 Latin square tool.

<table>
<thead>
<tr>
<th>Parameter/trait</th>
<th>Source</th>
<th>Mean square</th>
<th>F</th>
<th>p</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height, cm</td>
<td>Treatment</td>
<td>14.35</td>
<td>1.12</td>
<td>ns</td>
<td>12.8</td>
</tr>
<tr>
<td>Branch number</td>
<td>Treatment</td>
<td>0.76</td>
<td>0.90</td>
<td>&lt; 0.05</td>
<td>0.84</td>
</tr>
<tr>
<td>Leaf number</td>
<td>Treatment</td>
<td>0.91</td>
<td>1.01</td>
<td>ns</td>
<td>0.90</td>
</tr>
<tr>
<td>Flower head number</td>
<td>Treatment</td>
<td>2.41</td>
<td>5.60</td>
<td>&lt; 0.05</td>
<td>0.43</td>
</tr>
<tr>
<td>Flower head weight, kg</td>
<td>Treatment</td>
<td>4.50</td>
<td>2.85</td>
<td>ns</td>
<td>1.58</td>
</tr>
<tr>
<td>Biomass yield, kg/plot</td>
<td>Treatment</td>
<td>0.78</td>
<td>3.00</td>
<td>&lt; 0.025</td>
<td>0.26</td>
</tr>
<tr>
<td>Plant stand, thousand</td>
<td>Treatment</td>
<td>5.501</td>
<td>0.96</td>
<td>ns</td>
<td>5.752</td>
</tr>
</tbody>
</table>

ns means non-significant result

Oil content of chamomile flower heads gave 0.48% to 0.65% in the experiment. The data showed no definite trend of effect of manure and fertilizer. But the percent of oil in the treatments was found as average as in the plantation of chamomile growing areas of Europe and America. ANOVA data are presented in Table 7.

3.7 Results of Manure cum Fertilizer Trial on Chamomile, Year 2

Plant height ranged 53-62 cm (Table 8) was nearly significant between 10 and 20 t/ha. The height was found average and general for chamomile. Slight increasing trend in height was seen from the increased doses of manure and fertilizer.

Branch number presented in Table 8 showed similar trend in the response of FYM and chemical fertilizer as of plant height. There were 21.3 (10 t/ha) to 26.6 numbers of branches (NPK 60:40:20 kg/ha) emerged in a plant. However the data were found non-significant.

Leaf number (Table 8) varied from 16 to 19 but the means did not differ significantly between the treatments and also had no definite trend.

Flower head number presented in Table 8 varied from 15.1 to 20.5, the highest being in the chemical fertilizer applied treatment. Increasing trend was observed with the higher manure and fertilizer doses. The agronomic traits of chamomile calculated as grand means of three experiments are presented in graphic structure in Fig. 11.

Weight of 100 flower heads varied from 13.5 to 15.5 g per plant (Table 9). The data followed definite trend. Weight of flower heads increased markedly with the increased dose of manure and fertilizer.

Yield of flower head as calculated (Table 9) was found to be the lowest (1,361 kg/ha) in the treatment of FYM 10 t/ha and the highest (1,702 kg/ha) in NPK 60:40:20 kg/ha. The data were not significant between the treatments.

Fresh biomass yields of chamomile plants (Table 9) were weighed and converted into hectare basis. The fresh plant yield significantly (*p* < 0.05) varied, the highest (11,423 kg/ha) was under higher doses of manure and fertilizer than the lowest dose of manure (8,541 kg/ha).

Plant stands: the final stands of chamomile plants were counted at first harvesting of flower heads (Table 9). There was no definite variation of stands based on the doses of manure and fertilizer. However the least stand (635.5 ths./ha) was under NPK applied plots and
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**Fig. 11** Means of agronomic traits of chamomile tested in all the three different trials.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height, cm</th>
<th>Branch number</th>
<th>Leaf number</th>
<th>Flower head number</th>
</tr>
</thead>
<tbody>
<tr>
<td>FYM 10 t/ha</td>
<td>56.9</td>
<td>12.5</td>
<td>23.8</td>
<td>12.6</td>
</tr>
<tr>
<td>FYM 20 t/ha</td>
<td>49.8</td>
<td>11.1</td>
<td>17.7</td>
<td>11.7</td>
</tr>
<tr>
<td>N:P:K 60:40:20 kg/ha</td>
<td>59.4</td>
<td>25.3</td>
<td>20.8</td>
<td>18.5</td>
</tr>
<tr>
<td>Mean</td>
<td>55.3</td>
<td>23.8</td>
<td>17.7</td>
<td>18.3</td>
</tr>
</tbody>
</table>

**Table 9** Effect of manure and fertilizer on biomass production and oil content of German chamomile in Kathmandu valley, Gene Bank research field, year 2.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Weight of 100 flower heads (g)</th>
<th>Yield of flower heads (kg/ha)</th>
<th>Yield of fresh biomass (kg/ha)</th>
<th>Plant stand (ths./ha)</th>
<th>Oil content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FYM 10 t/ha</td>
<td>13.5</td>
<td>1.361</td>
<td>8.541</td>
<td>667.5</td>
<td>0.64</td>
</tr>
<tr>
<td>FYM 20 t/ha</td>
<td>14.5</td>
<td>1.601</td>
<td>10.666</td>
<td>670.0</td>
<td>0.70</td>
</tr>
<tr>
<td>N:P:K 60:40:20 kg/ha</td>
<td>14.3</td>
<td>1.702</td>
<td>10.293</td>
<td>615.0</td>
<td>0.63</td>
</tr>
<tr>
<td>N:P:K 60:40:20 kg &amp; FYM 10 t/ha</td>
<td>15.5</td>
<td>1.690</td>
<td>11.423</td>
<td>635.5</td>
<td>0.66</td>
</tr>
<tr>
<td>Mean</td>
<td>14.5</td>
<td>1.589</td>
<td>10.231</td>
<td>647.0</td>
<td>0.658</td>
</tr>
</tbody>
</table>

3.8 Fertility Status and Soil Analysis Result of Trial Plots

The soil of experimental plots in general was medium fertile, sandy loam with average content of...
Performance of Medicinal and Aromatic Chamomile (*Matricaria chamomilla* L.) under Different Planting, Manure cum Fertilizer Regimes in Kathmandu Valley

Fig. 12 Mean plant stand, biomass and flower.

Fig. 13 Grand means of oil content percent head yield of chamomile in three trials in chamomile flower heads of all trials.
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Fig. 14  First harvest, manure/fertilizer trial.

Fig. 15  General plantation view in western Tarai

Table 10  ANOVA result of manure cum fertilizer trial data (year 2) performed as 4 x 4 Latin square design (LSD).

<table>
<thead>
<tr>
<th>Parameter/trait</th>
<th>Source</th>
<th>Degree of freedom</th>
<th>Mean square</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height, cm</td>
<td>Treatment</td>
<td>3</td>
<td>12.83</td>
<td>0.50</td>
<td>ns</td>
</tr>
<tr>
<td>Branch number</td>
<td>Treatment</td>
<td>3</td>
<td>9.82</td>
<td>0.35</td>
<td>ns</td>
</tr>
<tr>
<td>Leaf number</td>
<td>Treatment</td>
<td>3</td>
<td>6.77</td>
<td>2.18</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Flower head number</td>
<td>Treatment</td>
<td>3</td>
<td>0.84</td>
<td>0.61</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Flower head weight, kg/ha</td>
<td>Treatment</td>
<td>3</td>
<td>0.23</td>
<td>0.28</td>
<td>ns</td>
</tr>
<tr>
<td>Biomass yield, kg/ha</td>
<td>Treatment</td>
<td>3</td>
<td>11,947</td>
<td>0.31</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Plant stand, ths./ha</td>
<td>Treatment</td>
<td>3</td>
<td>1,023</td>
<td>0.28</td>
<td>ns</td>
</tr>
<tr>
<td>Oil content, %</td>
<td>Treatment</td>
<td>3</td>
<td>0.01</td>
<td>1</td>
<td>ns</td>
</tr>
</tbody>
</table>

ns means non-significant result in the analysis of variance (ANOVA) found between the treatment means.

Table 11  Composite soil samples results and status of the experimental plots.

<table>
<thead>
<tr>
<th>Locations of experimental plots</th>
<th>N, %</th>
<th>P2O5 kg/ha</th>
<th>K2O, kg/ha</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>NARI building land</td>
<td>1.1</td>
<td>179</td>
<td>470</td>
<td>Sand, %</td>
</tr>
<tr>
<td>PPD research field</td>
<td>0.9</td>
<td>135</td>
<td>517</td>
<td>Silt, %</td>
</tr>
<tr>
<td>Gene Bank field</td>
<td>1.2</td>
<td>177</td>
<td>320</td>
<td>Clay, %</td>
</tr>
<tr>
<td>Mean</td>
<td>1.1</td>
<td>163.7</td>
<td>435.7</td>
<td>Class</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sandy loam</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Loam</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Silty loam</td>
</tr>
</tbody>
</table>
Performance of Medicinal and Aromatic Chamomile (Matricaria chamomilla L.) under Different Planting, Manure cum Fertilizer Regimes in Kathmandu Valley

nutrient elements. It was evident from the results of soil samples taken and analyzed according to the standard method. Composite samples were collected from all replications and analyzed in the soil lab of SSD, NARI, Khumaltar. The mean values of N, P, K, texture are presented in Table 11.

There was slight variation (0.9%-1.2 %) in N content, the highest (1.2%) being in the soil of Gene Bank field, and the lowest (0.9%) in the soil of Plant Protection Division (PPD) research field. Phosphorus (P₂O₅) was found the lowest (135 kg/ha) in PPD research filed. Potassium (K₂O) was the highest (517 kg/ha) compared to Gene Bank field (320 kg/ha). The soil contained more sand in NARI and PPD fields (47%-59%) and more silt (43%-52%) in Gene Bank and PPD fields. Overall the soils could be classified as loamy to sandy and silt loam according to textural class (Table 11).

Nutrient requirements for cereal crops in the soils of Nepal have been estimated in general by SSD, NARC. Accordingly, rates of major elements vary: nitrogen (N) 40-120 kg/ha, phosphorus (P₂O₅) 20-60 kg/ha, potassium (K₂O) 20-40 kg/ha. These doses of fertilizers are applied in most major crops grown in the country under various soil conditions. The NPK 60:40:20 kg/ha is considered as an optimum ratio of nitrogen, phosphorus and potassium and is the starting dose of for many crops.

3.9 Analysis of Soil

Samples of soils were taken and analyzed according to the standard method employed in soil analysis. Composite samples were collected from all replications of the three treatments and those were analyzed in the soil lab of Soil Science Division, NARI, Khumaltar. The results are presented Table 11.

4. Conclusions

Based on the two years research findings of three experiments following conclusions are drawn: both new and old genotype of German chamomile (Matricaria chamomilla L.) grows well in Kathmandu valley planting in Dec.-Jan. The new genotype is better to cultivate in terms of flower and oil yield. Continuous sowing in line of shallow furrow is better planting method. Suitable row spacing is 40 cm. The rate of FYM may vary from 10 to 20 t/ha based on fertility status of soil. While applied in combination, the FYM 10 t/ha plus N:P:K 60:40:20 kg/ha is better in medium fertile soil.

5. Recommendation

The researcher would like to recommend the findings and technologies to the farmers and residents in Kathmandu valley and similar agro-ecological conditions. Now farmers can cultivate chamomile commercially in their suitable land for generating income. The landless also can grow in kitchen garden or as pot culture for herbal drink, medicinal and other purposes. Irrigation is needed for successful cultivation if the soil will be dry during growing period. Plant spacing/density experiment is suggested to carry out for better confirmation of the spacing.

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References


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