

**EVALUATION OF KALMEGH (*Andrographis paniculata*)
GERMPLASM UNDER JAMMU SUBTROPICS**

**By
Aatish Kumar Sharma
(J-18-M-564)**

Thesis submitted to Faculty of Postgraduate Studies
in partial fulfillment of the requirements
for the degree of

**MASTER OF SCIENCE
IN
FORESTRY**

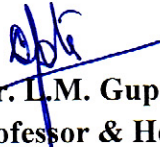


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Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu
Main Campus, Chatha, Jammu 180009**

2021

CERTIFICATE-I


This is to certify that the thesis entitled “**Evaluation of Kalmegh (*Andrographis paniculata*) Germplasm under Jammu Subtropics**” submitted in partial fulfillment of the requirements for the degree of **Master of Science in Forestry** to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu is a record of bonafide research, carried out by **Mr. Aatish Kumar Sharma**, Registration No. **J-18-M-564** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that such help and assistance received during the course of investigation have been duly acknowledged.


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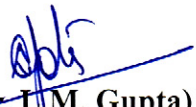

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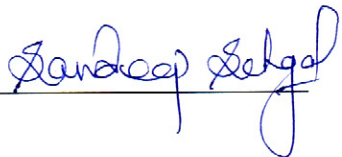

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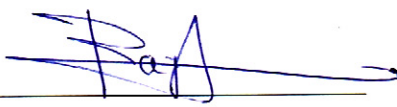
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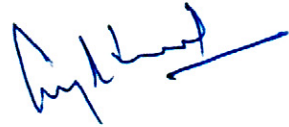


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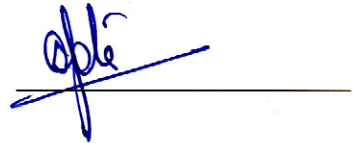
CERTIFICATE – III

This is to certify that the thesis entitled “**Evaluation of Kalmegh (*Andrographis paniculata*) Germplasm under Jammu Subtropics**” submitted by **Mr. Aatish Kumar Sharma**, Registration Number **J-18-M-564**, to the Faculty of Post Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu in partial fulfillment of the requirement for the degree of **Master of Science in Forestry** was examined and approved by the Advisory Committee and External Examiner on **19-01-2021**.

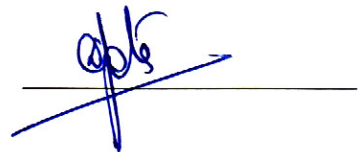


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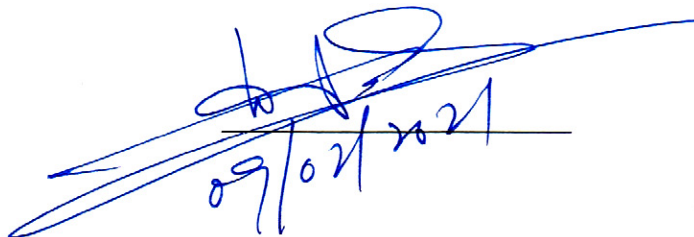
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“Feeling gratitude and not expressing it is like wrapping a present and not giving it”.

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Words once printed have life of their own.

Aatish

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ABSTRACT


Title of Thesis : **Evaluation of Kalmegh (*Andrographis paniculata*) Germplasm under Jammu Subtropics**
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Abstract

Kalmegh (*Andrographis paniculata* Nees) belonging to the family Acanthaceae is an important medicinal crop widely used in allopathic and traditional system of medicines. The medicinal value of the plant is due to the presence of active constituents andrographolide and neo-andrographolide in its aerial parts (leaves and stem), which are derivatives of diterpenoids. It is traditionally used for the treatment of common cold, diarrhea, fever, jaundice and as a health tonic for the liver and cardiovascular health. The present investigation was carried out at the Experimental Farm of Division of Agroforestry to evaluate different accessions of kalmegh for their growth and yield parameters under Jammu subtropics so as to know the information on the variability present in them and to identify the superior accession (s) for subtropics of Jammu. 14 accessions were evaluated and it has been observed that there was a wide range of variability observed for almost all the characters studied. Higher dry herbage yield per plant was observed in IC-622552 (42.41 g) followed by IC-622554 (39.25 g) and IC-622545 (33.14 g). Higher values of GCV and PCV were observed in dry herbage yield per plant (28.99 per cent, 30.20 per cent) and dry herbage yield per hectare (29.00 per cent, 30.19 per cent). Higher values for heritability accompanied with higher genetic gain was observed for number of leaves per plant (95.84 per cent, 112.74 per cent). However, higher genetic gain was observed for dry herbage yield per plant and dry herbage yield per hectare with 57.33 per cent and 57.40 per cent, respectively. All the characters and combinations were positively and significantly correlated with each other. Highly significant correlations values were observed for the trait pairs of fresh herbage yield per plant vs. dry herbage yield per plant ($r = 0.966$, $p = 0.01$), plant spread vs plant height ($r = 0.949$, $p = 0.01$), dry herbage yield per plant vs number of leaves per plant ($r = 0.934$, $p = 0.01$). Higher dry herbage yield per hectare was observed in accession IC-622552 (31.41 q ha^{-1}) and IC-622554 (29.07 q ha^{-1}). On the basis of growth and yield parameters, accessions IC-622552 and IC-622554 are superior over other accessions and are suitable for cultivation under Jammu subtropics.

Keywords: *Andrographis paniculata*, accessions, correlation, herbage yield, variability


Signature of Major Advisor


Signature of Student

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ABBREVIATIONS USED

%	Per cent
m	Meter
g	Gram
mt	Million tones
cm	Centimetre
ha	Hectare
kg	Kilogram
°C	Degree Celsius
<i>et al.</i>	And others
g	Gram
GCV	Genotypic coefficient of variation
PCV	Phenotypic coefficient of variation
RBD	Randomized Block Design
C.D _{0.05}	Critical difference at 5% level of significance
NBPGR	National bureau of Plant Genetic Resources
Fig.	Figure
amsl	Above mean sea level
FYM	Farm Yard Manure

Chapter-1

Introduction

INTRODUCTION

Jammu and Kashmir union territory (J&K UT), owing to its unique geographical location, physiographic features and varied agro-ecological conditions have been blessed with diversity of flora and fauna. Agriculture occupies an important place in the economy of Jammu and Kashmir union territory as about 70 per cent of its population derives its livelihood from agriculture and its allied sectors. Despite diversity of plants and animals coupled with diverse agro-climatic situations, J&K UT is far behind the national average in terms of production and productivity of almost all crops. The land holdings are relatively small and scattered, and majority of the farmers fall in the small to marginal category and the farmers are not financially sound, especially in *kandi*, mid hill and high hill rainfed situations. In Jammu division, 70 per cent area is rainfed and only 30 per cent is under irrigation, whereas in Kashmir division, 40 per cent area is rainfed and 60 per cent is under irrigation. Due to crop failure in rainfed areas especially in *kandi* in the present scenario of climate change/global warming, the farmers especially rural youth are shifting from agriculture to other ventures for earning. To enhance the income of farmers and to retain rural youth in agriculture, there is need to diversify the existing cropping pattern.

Besides secondary agriculture viz. bee keeping, mushroom cultivation, piggery, dairy farming, fishery, medicinal and aromatic plants are among other crops i.e. spices, fruits, flowers, vegetables, plantation crops etc. which can be a viable option for diversification in agricultural lands and have potential to increase the farm income.

Medicinal plants are now regaining importance for their use as therapeutic agents due to free from side effects compared to synthetic drugs. Now western community has also shown keen interest in the botanicals for their use as curative agents. This can be evident from the fact that 80 per cent of the world's population relies on medicinal plants for their primary health care.

Global herbal market is around US \$70 billion which as per WHO estimates expected to be US \$5trillion by the year 2050. With a wealth of 6,600 medicinal plants, India is the second largest exporter of AYUSH and herbal products in the world after China and both countries together produce more than 70 per cent of the total global demand for herbal products (FICCI, 2017). The Indian herbal market is valued at ₹ 5,000 crores currently, with an annual growth rate of 14 per cent. More than 30,000 branded and 1,500 traditional AYUSH products are available in the country (FICCI, 2017). The area under these crops has increased over the years with the annual growth rate of 1.12 per cent per annum. Cultivation of medicinal and aromatic crops has increased from 2,62,000 hectares during 2005-06 to 6,33,900 hectares in 2015-16. Similarly, the production has increased from 2,02,000 tonnes in 2005-06 to 10, 22,500 tonnes with an annual growth rate of 2.76 per cent per annum (Chowti *et al.*, 2018).

Medicinal and aromatic plants with low water and less fertile soil requirement can be boon for framers in rainfed/*kandi* areas. There are number of species like Aloe, Amaltas, Maleen, Ashwagandha, Makoi, Giloe, Kalihari, Khair, Shatavar, Guggal, Babool, Khejri, Silybum, Amla, Harad, Bahera, Kalmegh etc. which have low water requirement, can be grown on marginal lands, and thus are suitable for diversification in dryland farming in subtropical area of Jammu. *Andrographis paniculata* is one such herbaceous species belonging to family Acanthaceae and commonly known as Kalmegh, 'King of bitters', 'Green Chirayta', Kirayat, Bhui Nimba, Nelaberu, Nila Vembu etc. (Maheshwari *et al.*, 2004). It is native to India and Sri Lanka and widely cultivated in southern and south eastern Asia. In India, it is mainly cultivated in the states of Assam, Bihar, Kerala, Karnataka etc. Above ground herbage is the economic part of the plant which is used both in traditional system of medicines (Ayurveda, Unani) and in allopathy. The therapeutic activities of this plant are due to the presence of diterpene lactone called andrographolide which is bitter in nature and another important constituent which is non-bitter compound called neo-andrographolide. These compounds possess antipyretic, hepatoprotective, hypoglycaemic, choloretic, antidiarrheal, immunostimulant, anti-inflammatory, antimalarial, antihypertensive, properties besides inhibitor against HIV (Raina *et al.*, 2013).

In Indian System of Medicines, Panchang (stem, leaf, flower, seed and root) of the plant is being used as a stomachic, tonic, antipyretic, antifertility, antibacterial and anti-oxidant agent. Kalmegh is the component of over 50 per cent of the multi-ingredient herbal formulation available in India for the treatment of liver ailments. The herb is official in Indian Pharmacopoeia as a predominant constituent of at least 26 ayurvedic formulations used to treat liver ailments (Balachandran and Govindarajan, 2005). It is used in various ailments like throat, dysentery, cancer, hepatotoxicity, cough, cold, headache, edema, inflammation, arthritis, rheumatism, multiple sclerosis, diarrhoea, dysentery, cholera, diabetes, piles, fever, hepatitis, herpes, leprosy, loss of appetite, jaundice, malaria, dyspepsia, dermatitis, pneumonia, tuberculosis, chicken pox etc (Anju *et al.*, 2012).

Kalmegh is an annual, branched, herbaceous plant growing to a height of 30– 110 cm in moist and shady places having stem acutely quadrangular, slender, much branched, easily broken fragile texture which is dark green in colour, squared in cross section with longitudinal furrows and wings along the angles. The leaves are simple, opposite, lanceolate, glabrous, lance- shaped, 2–12 cm long, and 1–3 cm wide with hairless blades measuring up to 8 centimeters long by 2.5 wide. Margin of the leaves are acute and entire or slightly undulated and upper leaves often bract form with short petiole. The flowers are small in size, borne in spreading racemes which possess botanical features of calyx 5- partite, small, linear; corolla tube narrow, about 6 mm long; limb longer than the tube, bilabiate; upper lip oblong, white with a yellowish top; lower lip broadly cuneate, 3- lobed, white with violet markings; stamens 2, inserted in the throat and far exerted; anther basally bearded. Superior ovary, 2-celled; style far exerted. Inflorescence of the plant is characterized as patent, terminal and axillary in panicle, 10–30 mm long; bract small; pedicel short. The fruit of the plant is a capsule which is erect, linear-oblong, 1–2 cm long and 2–5 mm wide, compressed, longitudinally furrowed on broad faces, acute at both ends, thinly glandular-hairy which contains many yellow brown seeds which are very small in size and sub quadrate (Kumar *et al.*, 2012).

The plant is cultivated as a *kharif* season crop. It is helophyte and therefore prefers a sunny situation. Propagation is generally done through seeds; however, it can

also be propagated by inducing rooting in cuttings. The seeds are sown during May-June. The seedlings are transplanted at a distance of 30 cm x 45 cm in the last week of July. Two or three irrigations may be required during the dry periods. It flowers during August – November. The plant is collected at maturity i.e. after complete flowering and fruiting. Depending upon area of cultivation harvesting is done in October - November. After harvesting, the whole plant is dried in shade by spreading on the floor for 7-8 days. During this period, it is protected from dew at nights.

Jammu division occupy a geographical area of 26,293 km² out of which about 9.64 per cent area (2534.64 km²) is *kandi* which covers parts of Jammu, Samba, Kathua, Reasi and Udhampur districts. The *kandi* area with low annual rainfall (<950 mm) is characterized by undulating topography, a deep water table, low soil organic matter, light soil texture, land covered with stones and frequent droughts. Extreme water stress is experienced during summers and winters and even water for drinking becomes scarce (Sharma and Sharma, 2011). Diversification through drought resistant medicinal plant species may provide livelihood security to the farming community, besides the restoration of ecological balance of the region.

To boost cultivation of kalmegh in subtropical area of Jammu region, it is imperative to identify and select the promising genotypes among the existing population. Keeping this in mind a field study entitled “Evaluation of Germplasm of Kalmegh (*Andrographis paniculata*) under Jammu Subtropics” was conducted with following objectives:

- Evaluation of different genotypes of kalmegh for growth and herbage yield
- Identification of superior genotype(s) for Jammu region.

Chapter-2
Review of Literature

REVIEW OF LITERATURE

The relevant literature pertaining to the present investigation entitled “Evaluation of Germplasm of Kalmegh (*Andrographis paniculata*) under Jammu Subtropics” is reviewed under following heads:

- 2.1 Importance of Kalmegh
- 2.2 Screening of germplasm
- 2.3 Production techniques of Kalmegh

2.1 Importance of Kalmegh

Genus *Andrographis* belonging to family Acanthaceae consists of 28 species of small annual herbs essentially distributed in tropical Asia. *Andrographis paniculata*, a herbaceous plant is commonly known as a ‘king of bitters’ and kalmegh in Hindi. It is a drug well known as a ‘green chiretta’ and is native to India and Sri Lanka (Maheshwari *et al.*, 2004). Kalmegh has been used for centuries in India for the treatment of various ailments. The panchang includes stem, root, flower, seed and root of the plant is being used in various formulation of Indian system of medicine (Pandey and Mandal, 2010). It is widely cultivated in southern and southeastern Asia, where it is used to treat infections and some diseases, often being used before antibiotics were created. Above ground aerial part of the plant is used for medicinal purposes (Kumar *et al.*, 2012).

Kalmegh is recommended in Charak Samhita dating to 175 B.C for treatment of Jaundice along with other plants in multi-plant preparation. It has been used traditionally for sluggish liver as antidote in case of colic dysentery and dyspepsia. In traditional Asian medicine, it is long known as immune system booster (Katta *et al.*, 2007). It has a wide range of medicinal and pharmacological application. It is used in both traditional system of medicine and modern therapy and exhibit anti-inflammatory, anti-HIV, antibacterial, antioxidant, antiparasitic, antispasmodic, antidiabetic, anticarcinogenic, antipyretic,

hepatoprotective, nematocidal and various other activities. Among many active chemical constituents, andrographolide, neo-andrographolide and dehydro-andrographolide are most important bioprotectants with wide range of therapeutic applications. It has also been reported that kalmegh is well tolerated at very high dose without any toxic effects (Niranjan *et al.*, 2010).

2.2. Screening of germplasm

Misra *et al.* (2005) reported that harvesting time also influences the variability as well as productivity in kalmegh. The variability in kalmegh genotypes was investigated, which resulted in the development of CIM–Megha variety by CIMAP, Lucknow. This variety is characterized by open canopy type with a branch angle of 60 degree from the main stem, early maturity, tolerant to iron deficiency, 32-40 q ha⁻¹ herb yield with 2.33-3.18% andrographolide (against 1.79% in check) and 1.32% neo-andrographolide content.

Sharma *et al.* (2009) studied variability in locally collected 15 genotypes of Kalmegh from Chhattisgarh and adjoining states. Three different variability parameters namely morphological, molecular and chemo-typing of active ingredient content were employed. The plant height ranged from 21.44-58.67 cm, number of branches ranged from 18.44-33.44 cm, number of leaves ranged from 83.11-149.78 and dry weight of plant 30–50 g. Wide variation was recorded with respect to quantitative characters and RAPD profiles. It has been concluded that simultaneously morphological, molecular and biochemical analysis are useful for characterizing genetic diversity and defining relationships between kalmegh germplasm. It also gave possible indications to the phytochemical variation of different genotypes which were due to the genetic differences.

Pandey and Mandal (2010) conducted a field experiment of kalmegh collected from five locations of Madhya Pradesh and Chhattisgarh to study for their morphological characteristics and diterpene content to find superior genotype. The average amount of dry weight per plant and andrographolide content was 16.58 to 18.92 g and 1.07 to 2.24 g, respectively. The difference in growth characteristics among the plant collected from different locations were not significant and the andrographolide content among the plants

from different locations was statistically significant. The study revealed that those populations were potential important sources for breeding, improvement of cultivars and best sources for obtaining high drug yield.

Raina *et al.* (2013) evaluated 22 accessions of kalmegh collected from various geographical regions of India to identify suitable genotype with high andrographolide content at NBPGR, New Delhi. These were harvested after 105 days of planting. The plant height ranged from 36.53-47.00 cm, number of primary branches ranged from 19.47-29.07, herbage yield (FWB) ranged from 425.00-810.0 g and herbage yield (DWB) ranged from 161.33-309.67 g. Phenotypic coefficient of variation varied from 8.02-16.53 per cent. Four accessions viz; IC 342139 (2.51%) from Jhansi, IC 471916 (2.16%) from Solan, Himachal Pradesh, IC 111291 (2.20%) and IC 210635 (2.13%) from Tamil Nadu were identified promising based on high andrographolide content (>2.0%).

Gangopadhyay *et al.* (2014) evaluated 31 accessions of kalmegh by using random amplified polymorphic DNA (RAPD) at Anand, Gujrat. Sixteen primers generated 156 (92.3%) polymorphic bands with an average of 9.75 polymorphic bands per primer. Polymorphic information content (PIC) ranged from 0.83 to 0.91 with an average of 0.880. Jaccard's similarity coefficients for RAPD primers ranged from 0.23 (AS-19/IC 260035) to 0.89 (AL-1/AS-36) with a mean genetic similarity of 0.59. The UPGMA based dendrogram grouped the genotypes in 11 different clusters at a cut off value of 0.60. The results indicated that RAPD could be effectively used for genetic diversity analysis in *Andrographis paniculata* as it is reliable, rapid and superior to those based on pedigree information.

Kumar *et al.* (2014) evaluated 44 accessions of kalmegh out of 155 accessions collected from different parts of the country. These 44 accessions were grown for characterization, evaluation and identification of trait-specific germplasm using nine important quantitative traits viz. plant height, number of primary and secondary branches, leaf length, leaf width, herbage yield and andrographolide content. Among the traits studied, the highest variability was observed for herbage yield on fresh weight basis (CV=16.95%) followed by herbage yield on dry weight basis (CV=15.98%) and andrographolide content (CV=13.34%). The promising accessions identified were

IC471919 for herbage yield (fresh weight basis) collected from Bilaspur (Himachal Pradesh) and IC342138, IC471895 with high andrographolide content from Amarkantak (Madhya Pradesh).

Twenty selected lines of kalmegh were evaluated to find out a suitable variety favourable for eastern Uttar Pradesh conditions. The data were recorded on plant height, number of primary branches per plant and fresh as well as dry herbage yields. The plant height varied significantly from 57.20 to 82.40 cm. The highest plant height was in IC-210699 (82.40cm) followed by IC-210635 (80.25cm) and IC-211295 (79.55cm). However, lowest plant height was in IC-471917 (57.20cm). Number of primary branches per plant ranged significantly from 21.70 to 27.90. Maximum number of primary branches per plant was recorded in IC-210635 (27.90) followed by IC-111291 (27.40) and IC-211295 (26.70). However, minimum number of primary branches per plant was recorded in IC-471912 (21.70). Fresh herbage yield ranged significantly among the 20 lines from 84.72 to 175.95 q ha⁻¹. Maximum fresh herbage yield was obtained in IC-260035 (175.95 q ha⁻¹) followed by IC-265622 (170.22 q ha⁻¹) and IC-471918 (164.38 q ha⁻¹). Minimum fresh herb yield was noted in IC-210699 (84.72 q ha⁻¹). IC-265622 had better dry herbage yield (61.45 q ha⁻¹) as compared to IC-471918 (56.39 q ha⁻¹) and IC-265622 (55.25 q ha⁻¹) while minimum dry herbage yield of 25.22 q ha⁻¹ was recorded in IC-210699 (DMAPR, 2016).

Manjesh *et al.* (2016) evaluated 20 kalmegh genotypes to study the PCV, GCV, h² and GA percent and diversity pattern among the collected genotypes. Among all the genotypes higher estimates of GCV, PCV, h², GA per cent was observed for the characters leaf to stem ratio, (37.50%, 38.99%, 93.03%, 74.53%), fresh weight of leaf (39.23%, 40.62%, 93.26%, 78.04%), dry weight of leaf (48.79%, 49.81%, 95.91%, 98.43%), dry weight of stem (20.82%, 22.32%, 86.95%, 39.99%), respectively. Genetic diversity was estimated through D2 statistic and the genotypes were grouped into 10 clusters. The distribution patterns indicated that the maximum number of genotypes (4) were grouped into clusters I and III. Maximum intra cluster distance of 10.20 (cluster VII) and inter cluster distance of 36.95 (between clusters X and VII), hence the genotypes with clustering patterns indicated that genotypes falling in cluster X (IIHR Kalmegh 2)

and VII (IIHR Kalmegh 6 and IIHR Kalmegh 9) can be used in hybridization programme to generate wide range of transgressive segregants in population for developing varieties/hybrids with higher yield coupled with higher chemical content.

Nagvanshi and Tirkey (2016) evaluated 22 accessions with 2 checks i.e, Anand Kalmegh-1 (DMAPR) and Simmegha (CIMAP) to study the PCV, GCV, GA per cent and diversity patterns among the collected accession. The study revealed that PCV value was slightly higher than GCV indicating the slight influence of environment in the expression of the accessions. GCV, PCV, h^2 and GA per cent was observed for the characters number of tertiary branches with 49.72 per cent, 50.10 per cent, 98.80 per cent and 99.82 per cent, respectively and dry herbage yield with 44.87 per cent, 45.96 per cent, 95.30 per cent and 90.24 per cent, respectively. The accession with IKM-1, IKM-2, IKM-7, IKM-20, IKM-23, IKM-24 can be used as potential donors for hybridization programme to develop variety with higher yield potential.

Initial evaluation trial with 8 test entries and three checks (INGR07041, AK-1, AL-1) of kalmegh was conducted at thirteen locations viz., Mandsaur, Faizabad, Anand, Kalyani, Raipur, Hisar, ICAR-DMAPR, Jorhat, Pusa, Trichur, Akola, Bhubaneswar and Coimbatore with an objective to identify superior varieties with high yield and quality. Across location, DMAPR AP18 recorded maximum dry biomass yield (5337 kg ha^{-1}) which was followed by DMAPR AP35 ($5076.0 \text{ kg ha}^{-1}$). Andrographolide content (%) was maximum in AL-1 (1.67) which was followed by DMAPR AP35 (1.624) and DMAPR AP18 (1.471) across location. Andrographolide yield (kg ha^{-1}) was found maximum (96.99 kg ha^{-1}) in DMAPR AP35 which was followed by DMAPR AP13 and AK-1 with yield of 92.10 kg ha^{-1} and 91.75 kg ha^{-1} , respectively (DMAPR, 2017).

Liphan and Detpiratmongkol (2017) evaluated the effect of different shading levels on growth and yield of kalmegh during December, 2014 to April, 2015, at Bangkok. There were four local Kalmegh varieties (Phisanulok 5-4, Prachinburi, Ratchaburi and Phichit 4-4) and 5 shading levels (0%, 20%, 40%, 50% and 80% of shading). The results showed that Prachinburi variety gave the highest number of branches plant^{-1} , number of leaves plant^{-1} , leaf area, shoot dry weight and leaf dry weight yield followed by Ratchaburi, Phichit 4-4 and Phisanulok 5-4 varieties, respectively. It

was concluded that Kalmegh variety Prachinburi performed better in terms of highest growth and yield grown under 20% shading condition.

To identify superior genotype with high yield and quality in kalmegh, an initial evaluation trial (IET) with 11 test entries and two checks (INGR07041 and AK-1) was conducted at ICAR-DMAPR, Anand. The data showed that the plant height was significantly higher in entry AL1 (74.10cm) which was at par with AAP16 (73.10 cm) and DMAPR AP13 (69.73cm). Plant spread was significantly superior in the entry DMAPR AP13 (137.50 cm) which was at par with check variety i.e AK1 (116.33 cm). Differences in the collar diameter were non-significant among the entries. Number of primary branches per plant was significantly higher in DMAPR AP35 (44.33) which was, however, at par with DMAPR AP13 (43.67), NDKL 11 (41.00), DMAPR AP18 & NDKL 10 (39.33) and AAP 36 & AL1 (38.67). Fresh and dry herbage yield was significantly higher in DMAPR AP13 (13074.10 kg ha⁻¹; 7228.94 kg ha⁻¹). However, entries DMAPR AP35 (11192.07 kg ha⁻¹), AK1 (10652.02 kg ha⁻¹), DMAPR AP18 (10594.78 kg ha⁻¹) and AAP 16 (10111.03 kg ha⁻¹) were at par with DMAPR AP13 in the case of fresh herbage yield. Andrographolide content (%) ranged from 1.21% to 1.68% (DMAPR, 2018).

Kumar *et al.* (2018) conducted a trail in which 25 collections of kalmegh collected across its natural growing zone were evaluated under uniform edapho-climatic conditions of Jharkhand. Plants in all the collections were harvested before flowering stage to evaluate its different biochemical constituents. Before flowering stage, germplasm like JHAP₁ (2.39%), JHAP₃ (2.21%), OAP₁ (2.00%), CHAP₁ (2.36%), CHAP₂ (2.03%) gave maximum andrographolide content. Maximum andrographolide yield was recorded in JHAP₃ (33.33 kg ha⁻¹), OAP₃, OAP₅ CHAP₁ and MPAP₄. Maximum neo-andrographolide content was recorded for JHAP₃ (2.93%) followed by JHAP₄, OAP₁ and OAP₂; however, maximum neo-andrographolide yield was recorded in JHAP₃ (46.78 Kg ha⁻¹) followed by JHAP₄, OAP₁, MPAP₁. Maximum diterpenoid yield was recorded in JHAP₃ (82.11 Kg ha⁻¹) and OAP₁. Maximum production of andrographolide, neo-andrographolide and diterpenoid yield was recorded if harvested before flowering stage.

JHAP₁, JHAP₃, MPAP₁ OAP₁, CHAP₁ were screened out as best collections under the climatic and edaphic conditions of Jharkhand.

Sixty-three accessions of kalmegh were evaluated for yield and other agronomic traits. Significant variations were observed for plant height (cm), number of branches, fresh herbage yield and dry herbage yield. Plant height ranged from 25.6-75.8 cm, number of branches ranged from 19.3-41.5, fresh herbage yield ranged from 2222.2 to 19814.8 kg ha⁻¹ and dry herbage yield range from 740.0 to 7407.4 kg ha⁻¹. Accessions IC 0342135 (7407.4 kg ha⁻¹), IC 0111288 (7037.0 kg ha⁻¹), IC 0589231 (6666.7 kg ha⁻¹), AK-1 (6111.1 kg ha⁻¹) and IC-565468 (6111.1 kg ha⁻¹) recorded higher dry herbage yield (DMAPR, 2019).

2.3. Production techniques of kalmegh.

Muniramappa *et al.* (1997) conducted an experiment to study the macro nutrient (NPK) requirement of Kalmegh (*Andrographis paniculata*). The treatments consisted of four levels of N (0, 50, 75 and 100 kg ha⁻¹), four levels of P (0, 25, 50 and 75 kg ha⁻¹) and one level of K (50 kg ha⁻¹) with four replications. Application of 100 kg of Nitrogen per hectare recorded the maximum plant height (34 cm), plant spread (646 cm²), number of branches (21), number of leaves (36), leaf area (116 cm²), fresh and dry weight per plant (15.3 g and 9 g, respectively) and per hectare (3.01 t and 1.3 t, respectively). However, it was at par with application of 75 kg N ha⁻¹ for most of the yield characters. Application of phosphorus at 75 kg ha⁻¹ recorded the highest plant height (32 cm), plant spread (553 cm²), number of branches (20) and leaves (35), fresh and dry weight per plant (12 g and 7 g, respectively), herbage yield per hectare (2.79 t and 1.17 t, respectively) and andrographolide content (3.58%). The interaction of N and P showed significant response to yield parameters than growth attributes.

Ashok *et al.* (2002) conducted an experiment to study the effect of aging on andrographolide content in kalmegh to establish the best harvesting time. The growth and yield parameters were recorded at 30, 60, 90, 120 and 150 days after sowing. Best harvesting time was reported to be at 120 days after sowing which contain higher biomass and maximum andrographolide content.

Wankhade *et al.* (2005) conducted a field experiment for successive three years during *kharif* seasons to study the effect of time of planting and harvesting on the herb yield and quality of kalmegh. The treatment comprises of three planting dates (1st July, 16th July and 1st August) and three harvesting dates (16th October, 1st November and 16th November). It was concluded that the planting time of 1st July and harvesting time between 1st to 16th November were the most suitable for obtaining herbage yield (1481.2 and 1652.6 kg ha⁻¹, respectively), total yield of andrographolide (32.33 Kg ha⁻¹ and 29.13 kg ha⁻¹, respectively) and iron (1022.1 kg ha⁻¹ and 1090.8 kg ha⁻¹, respectively).

Sharanabasappa *et al.* (2007) found that intercropping of medicinal plants with teak plantations had some competitive effect on medicinal plants such as aloe, lemongrass and kalmegh due to their reduction in fresh and dry herbage yields when compared to their sole cropping. However, positive result was obtained with *Coleus*, where the fresh and dry weights of intercropped plants was equal to sole cropping because of higher relative crop yield indicating the compatibility of intercropping of *Coleus* with teak plantations.

Makwana *et al.* (2009) conducted an experiment to know the effect of different organic manures and spacing on yield and yield attributes of kalmegh -Panchang (*Andrographis paniculata*) under middle Gujarat conditions. The results indicated that the growth attributes such as plant height at harvest (71.36 cm) and plant breadth at harvest (23.89 cm) were significantly higher under treatment of 30 cm x 45 cm. Significantly the highest fresh (10335 kg ha⁻¹) and dry yield (4375 kg ha⁻¹) of kalmegh were recorded under treatment (30 cm x 45 cm) whereas, the growth attributes such as plant height at harvest and leaf : stem were significantly higher under application of FYM @ 10 t ha⁻¹. Significantly the highest fresh and dry yield of kalmegh (9952 and 4306 kg ha⁻¹, respectively) was obtained under application of FYM @ 10 t ha⁻¹.

Prabhu *et al.* (2009) studied the growth and yield parameters of kalmegh using different bio-stimulants producing positive results. Spraying of 2% Panchakavya + 0.2% Humic acid + 2% Moringa leaf extract combination resulted in higher plant height, number of branches, number of leaves, leaf area and leaf area index of kalmegh both at

60 and 90 days after planting. The same treatment also recorded the highest dry herbage yield of 1956 kg ha⁻¹ than the other treatments.

Singh *et al.* (2011) evaluated 4 strains (CIMAP/AP-3, CIMAP/AP-10, CIMAP/AH-89 and local check) of kalmegh at three population densities (74,074, 111,111 and 222,222 plants ha⁻¹) for growth behavior, biomass and diterpenoid lactones production at Central Institute of Medicinal and Aromatic Plants, Lucknow, India during July to November, 2004 and 2005. The strain CIMAP/AP-3 was found to possess desired agronomic traits. The advantage in biomass and diterpenoid lactones (andrographolide and neo-andrographolide) production with CIMAP/AP-3 over other strains was 33.4 - 79.4 and 31.6-70.7%, respectively. Planting at a closer spacing of 30 cm x 15 cm accommodating 2,22,222 plants ha⁻¹ produced maximum dry biomass and andrographolide and neo-andrographolide yield under the subtropical climate of North India.

Prashar *et al.* (2011) conducted a field study on kalmegh at dusty acre farm of JNKVV, Jabalpur. The results were evaluated on the basis of growth analytical parameter (viz. leaf area, leaf area index, crop growth rate, relative crop growth rate, leaf area duration, biomass duration and specific leaf area) as well as morpho-physiological (viz. plant height, number of leaves, number of branches, plant fresh weight, plant dry weight, leaves fresh and dry weight and herbage yield) parameters. The study revealed that all the selected parameters goes on increasing with crop growth stages. However, the specific leaf area increases up to 90 DAS and there after, it gradually decline up to 120 DAS indicating the maturity of crop. The herbage yield per plant after 120 DAS was recorded to be 33.88 g.

Bhattacharya *et al.* (2012) conducted a field experiment to study the abiotic stress like salinity (NaCl), water-deficit (PEG) and heavy metal (Cadmium) on germination, seedling growth and seed vigor index (SVI) of kalmegh at Shoolini University, Solan. They reported that seed germination was effected by three factors viz; PEG, NaCl and Cd (cadmium) and maximum degree of enhancement was found to be in PEG, whereas, stress caused by cadmium was much inhibitory.

Hemlatha and Suresh (2012) conducted a study to ascertain the effect of organic, inorganic and biofertilizers on growth and yield of kalmegh at Horticultural College and Research Institute, Periyakulam. In this study, seventeen treatment combinations were used. The results indicated highest plant height (56.54 cm), number of branches (22.65) and number of leaves (41.40), leaf area (128.34 cm²), dry biomass (2.639 t ha⁻¹) and fresh herbage (1392.22 kg ha⁻¹) and alkaloid content (0.739 %) were recorded in the treatment combination of 15 t FYM ha⁻¹ + 45:25:25 kg NPK ha⁻¹ +1 kg *Azospirillum* ha⁻¹.

Patel *et al.* (2012) conducted a field experiment under *kharif* season from 2007-08 to 2009-10 at Anand, Gujrat, to study the response of four replications with 16 treatment combinations comprising of four levels of organic manures viz; M₀ (Control), M₁ (FYM @ 10 t ha⁻¹), M₂ (Castor cake @ 1 t ha⁻¹) and M₃ (Vermicompost @ 2 t ha⁻¹) with four levels of spacing (S) viz., S₁ (30 cm x 15 cm), S₂ (30 cm x 30 cm), S₃ (30 cm x 45 cm) and S₄ (30 cm x 60 cm) as sub plots treatments on growth, yield quality and economics of kalmegh. Spacing had non-significant effect on growth parameters, yield and quality of crop. Although, higher values of yield components and economics of the crop were recorded under treatment combinations M₂ S₁ and M₁ S₁.

Semwal *et al.* (2016) conducted a study for 2 years to know the effect of planting geometries and weed control practices on growth and herbage yield of kalmegh. It was reported that growth related parameters like number of branches, plant spread and leaf area index were significantly influenced by the wider planting geometry over that of closure during both the years. It was also observed that keeping weed free condition aside, the weed management intergreted by the practices like application of pendimethalin 30 E.C. PE.@ 1.0 kg *a.i./ha* + quizalofop ethyl 5 E.C. P_oE @ 50 g *a.i./ha* at 3-5 leaves stage of weeds followed by mechanical weeding by hand hoe at 30-35 DAT and pendimethalin 30 E.C. PE @ 1.0 kg *a.i./ha* followed by mechanical weeding by hand hoe at 30-35 DAT proved effective in producing more plant height, number of branches, plant spread, leaf area index, dry matter accumulation by crop m⁻² and dry herbage yield ha⁻¹ as compare to remaining treatments during both the years. The experiment revealed that to get more dry herbage yield of kalmegh, integrated approach of pre and post-

emergence applied herbicides followed by mechanical weeding along with closure planting geometry produced the best result.

Goel and Duhan (2013) reported that growth attributes of kalmegh (plant height, number of primary branches, plant spread and dry weight of shoot) were enhanced significantly with the application of $12.5 \text{ mg P}_2\text{O}_5 \text{ kg}^{-1}$ soil along with FYM @ 12.5 t ha^{-1} as compared to the other treatments and the results were on par with higher level of fertilizer phosphorous (P) or FYM application. Application of FYM improved the andrographolide content significantly upto the level of 12.5 t ha^{-1} FYM in combination with fertilizer $12.5 \text{ mg P}_2\text{O}_5 \text{ kg}^{-1}$ soil compared to other treatments. Application of FYM @ $12.5 \text{ t ha}^{-1} + 12.5 \text{ mg P}_2\text{O}_5 \text{ kg}^{-1}$ soil was found to be the best treatment combination for the highest nutrients uptake by kalmegh.

Kumar and Kumar (2013) carried out a field experiment at Hissar to know the influence of four harvesting times (120, 135, 150 days after planting and at seed maturity) and four planting distances (30 cm \times 15 cm, 30 cm \times 10 cm, 20 cm \times 15 cm and 20 cm \times 10 cm) on growth, dry herbage biomass, seed yield and quality traits of *Andrographis paniculata*. The maximum values for dry herbage biomass yield (5.14 t ha^{-1}), net returns ($760.00 \text{ EUR ha}^{-1}$), B:C ratio (2.59), andrographolide content (2.63%) and total yield ($135.00 \text{ kg ha}^{-1}$) were observed 135 days after planting with an optimum planting distance of 30 cm \times 15 cm.

Shahjahan *et al.* (2013) conducted an experiment in Dhaka, Bangladesh which consisted of two factors viz. A: Three levels of organic fertilizers- control (T_1), vermicompost (T_2) and cowdung (T_3), B: Three spacing- 60 cm \times 30 cm (S_1), 60 cm \times 45 cm (S_2) and 60 cm \times 60 cm (S_3). They concluded that organic fertilizer and spacing individually and in combination has significant effect on growth and yield of kalmegh. Application of vermicompost in 60 cm \times 60 cm spacing gave the highest total dry weight plant⁻¹ (140.7 g) for attaining good growth contributing characters.

Mishra and Aruna (2014) conducted an experiment to find out the effect of INM on vegetative growth, flowering and fruiting of *Andrographis paniculata*. The results indicated that maximum growth i.e. plant height, number of branches, number of leaves,

leaf length and breadth, leaf area, land area occupied per plant and leaf area index, number of flowers and fruits was found in treatment combination of biofertilizers + chemical fertilizers + vermicompost compared to other treatments. The integrated use of biofertilizers, chemical fertilizers and vermicompost treatments significantly increased growth parameters of *A. paniculata*.

Pal *et al.* (2019) conducted an experiment at Experimental Farm, Nalanda College of Horticulture, Noorsarai, Nalanda in the year 2013-14 and 2014-15. The experiment was laid out assigning time of planting (Factor A) and planting geometry (Factor B) to assess the effect of date of planting and planting geometry on growth and yield of Kalmegh cv. CIM Megha. Pooled data on different growth and yield characters revealed 15th June as best time of planting of kalmegh and proclaimed highest values for plant height (75.46 cm), plant girth (7.69 mm), number of secondary branches, number of leaves per plant and total dry matter yield (31.75 q ha⁻¹). On the other hand spacing level of S₂ (30 cm x 20 cm) also recorded highest values for plant height (68.75 cm), plant girth (7.75 mm), number of secondary branched per plant, number leaves per plant and total dry matter yield (27.38 q ha⁻¹). The treatment combination of 15th June as time of planting and plant spacing of 30 cm x 20 cm found best for planting of kalmegh in the growing conditions of the Nalanda. It was followed by planting time 15th June and plant spacing of 30 cm x 15 cm for higher growth and yield of kalmegh.

Chapter-3
Material and Methods

MATERIAL AND METHODS

Studies on “**Evaluation of Kalmegh (*Andrographis paniculata*) Germplasm under Jammu Subtropics**” were carried out in the Agroforestry Experimental Farm, Sher-e- Kashmir University of Agricultural Sciences and Technology of Jammu during the year 2019-20. The details of the experimental site, experimental materials used and the methodology followed during the course of investigation are given here under the following headings:

- 3.1 Experimental site
- 3.2 Experimental details
- 3.3 Cultural practices
- 3.4 Experimental observations
- 3.5 Statistical analysis

3.1 Experimental site

3.1.1 Location

The experimental site is situated in subtropical Jammu region of Jammu and Kashmir Union Territory at an altitude of 332 m above mean sea level between 32^o40' N latitude and 74^o58' E longitude.

3.1.2 Climate and weather conditions

The experimental site experiences hot dry summers, humid rainy season and cold winter months. The average rainfall during the trial at the site is about 800 mm with 40 - 45 per cent of which is received during the month of July. The maximum temperature rises upto 40.5^oC during the month of June and minimum falls to 13^oC during the month of November. The monthly weather data recorded at Meteorological Observatory of SKUAST-Jammu, Chatha, for the year 2019-20 (July 2019 - Nov 2019) is given in Fig.1.

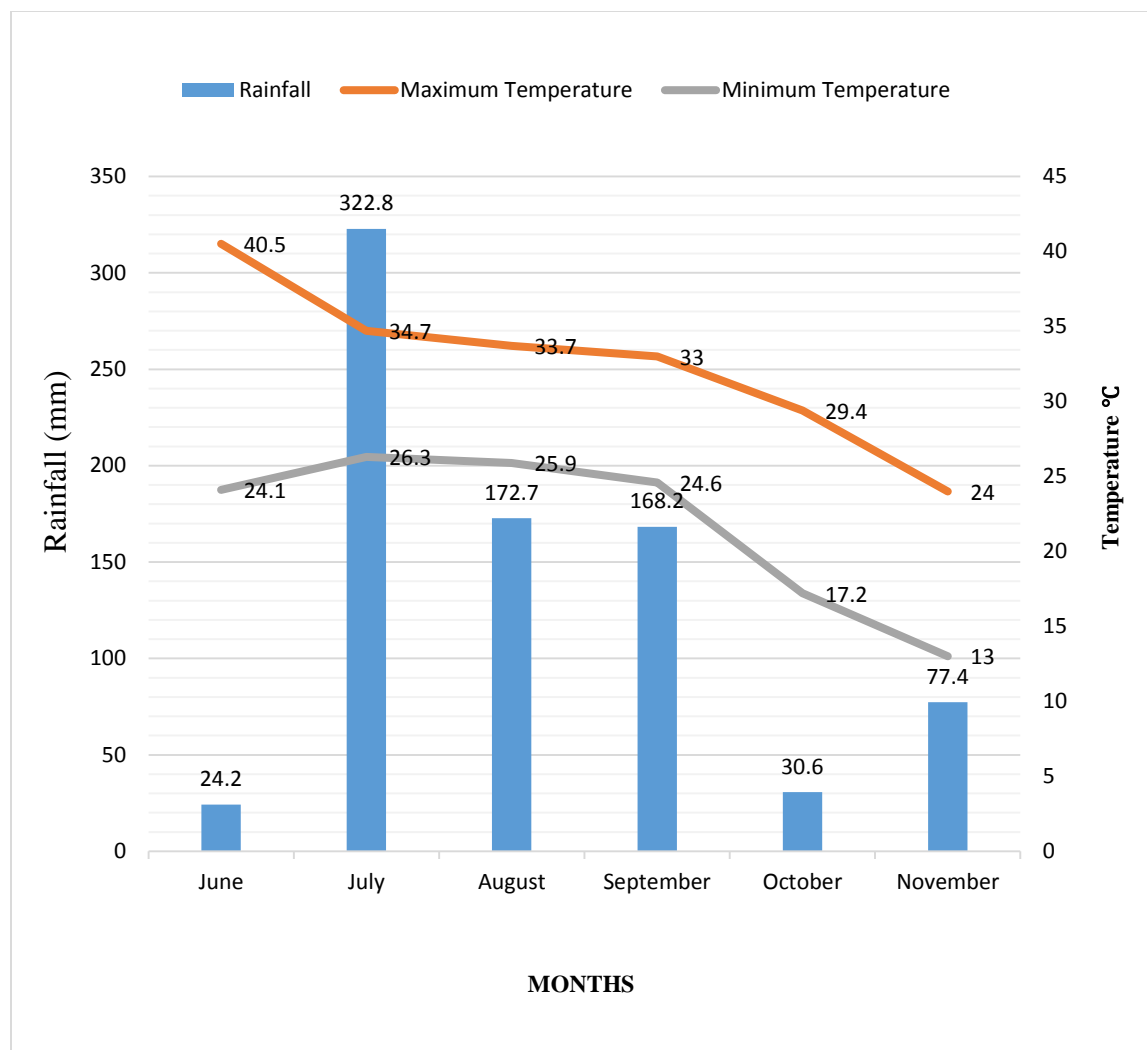


Fig. 1 Monthly meteorological data w.e.f. June, 2019 to November, 2019

3.1.3 Soil characteristics

For the analysis of the soil, five composite soil samples were collected from the experimental site at a depth of 0-15 cm before planting, following the procedure of random sampling (Peterson and Calvin, 1965). The collected samples were mixed thoroughly, air dried, grinded, sieved and kept in cloth bags for subsequent analysis. The soil was sandy loam in texture. The test values for different parameters after analysis are presented in Table 1.

Table 1: Physico-chemical properties of study area

S. No.	Parameters	Test Value	Method employed
1	Mechanical analysis		
	Soil Texture (%)		International pipette method (Piper, 1966)
	Sand	41.40%	
	Silt	45.50%	
	Clay	13.10%	
	Texture class	Sandy clay loam	
2	Chemical analysis		
	pH	7.30	1:2.5 Soil water suspension electrode pH Meter (Jackson, 1967)
	EC (dS/m)	0.16	1:2.5 Soil water suspension with systronic conductivity meter (Jackson, 1973)
	Available Nitrogen (kg/ha)	253.3	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
	Available Phosphorus (kg/ha)	16.1	Olsen <i>et al.</i> (1954)
	Available Potassium (kg/ha)	165.3	Ammonium acetate method (Jackson, 1967)

3.2 Experimental details

3.2.1 Experimental material and design

The field experiment was conducted during the *kharif* season of 2019-2020. The experiment was laid out in Randomized Block Design with 14 genotypes which were replicated thrice. The experimental material comprised of seeds of 14 accessions which were procured from NBPGR, New Delhi during April, 2019. The accession numbers of 14 genotypes are as under:

Table 2: Different accessions of kalmegh

S.No.	Accessions
1	IC-622544
2	IC-622545
3	IC-622556
4	IC-622547
5	IC-622548
6	IC-622549
7	IC-622550
8	IC-622551
9	IC-622552
10	IC-622553
11	IC-622554
12	IC-622555
13	IC-623172
14	IC-623182

3.3 Cultural Practices followed

3.3.1 Field preparation, sowing of seeds

The seeds were sown in the nursery in the last week of May, 2019. The field was prepared to a fine tilth and sunken beds of size 1.0 m x 1.5 m were prepared and the seedlings were transplanted on 25th June, 2019 at a spacing of 30 cm x 45 cm in each plot accommodating nine plants per plot. For nursery beds, FYM @ 20 Kg per square meter as basal dose is mixed in the soil. However, for the main field FYM @ 12.5 t ha⁻¹ is given as basal application. At the same time application of chemical fertilizers of nitrogen, phosphorus and potassium in the ratio of 45:25:25, respectively was added. All the cultural and plant protection practices were followed from sowing till the harvesting of kalmegh.

3.4 Characters studied

Observations were recorded individually on 15 randomly selected plants per treatment (five plants per replication). The detailed procedure adopted for recording observations in each character is described as under:

3.4.1 Plant height (cm)

Plant height was measured with a calculated rule from the soil surface to the top of the plant. The height of individual plant of kalmegh was measured using meter scale in cm. Measurement is done after 150 days of sowing and mean value was calculated for each germplasm.

3.4.2 Number of branches per plant

Total number of branches per plant emerging directly from the main stem was counted at maturity from the five tagged plants of each genotype and average value per plant was calculated.

3.4.3 Plant spread (cm)

Plant spread was recorded in centimeters from tip to tip of outermost leaves in east-west and north-south directions, using meter scale and average of two has been reported as plant spread (cm).

3.4.4 Number of leaves per plant

The number of leaves per plant of each selected genotype was counted before the harvest and reported as mean.

3.4.5 Fresh herbage weight per plant (g)

Each selected plant was cut at collar level, above-ground biomass (herbage) and root portion were separated. Then fresh herbage weight was recorded using digital electronic balance. The fresh herbage weight has been expressed in grams.

3.4.6 Dry herbage weight per plant (g)

The above-ground biomass (herbage) of each plant was dried in hot air oven at 65⁰ C for 48 hours. After drying, the herbage weight was recorded using digital electronic balance and reported in grams.

3.4.7 Fresh root weight per plant (g)

The fresh root weight was recorded using digital electronic balance. The fresh root weight has also been expressed in grams.

3.4.8 Dry root weight per plant (g)

Roots were dried in hot air oven at 65⁰ C in the paper bags for 48 hours. After drying, the shoot weight was recorded using digital electronic balance.

3.4.9 Root-Shoot ratio

The root: shoot ratio (dry weight basis) was obtained by dividing the dry root weight (g) by dry shoot weight (g) of each genotype.

3.4.10 Estimated dry herbage yield (q ha⁻¹)

The dry herbage yield per plant (g) recorded of each accession was multiplied with number of plants per hectare and expressed in quintals per hectare.

3.5. Statistical Analysis

The data pertaining to various characters were statistically analyzed using ANOVA. A variance analysis was computed for each variable and covariance analysis for each pair of variables. The mean values of 15 randomly selected plants from each genotype were used for statistical analysis. The statistical techniques followed are as under:

3.5.1 Analysis of variance

The statistical analysis for each character was carried out on mean values. The data was subjected to analysis of randomized block design as suggested by Pillai and Sinha (1968). The ANOVA table was set up as:



Fig. 2a



Fig. 2b

Figs. 2 a&b: Field preparation, lay out of experiment and transplanting of seedlings



Fig. 3

Fig. 3: General view of experiment

Source of variation (F)	d.f.	Mean sum of squares	Variance ratio
Replication	(r-1)	Mr	Mr/Me
Treatment	(t-1)	Mt	Mt/Me
Error	(r-1)(t-1)	Me	

Where,

r = Number of replications

t = Number of treatments

Mr = replication mean square

Mt = treatment mean square

Me = error mean square

The standard error and critical differences were calculated as follows

$$\text{S.E (d)} \pm = \frac{\sqrt{2 \times \text{Me}}}{r}$$

$$\text{C.D. at 5\%} = \text{S.E (d)} \times t_{5\%} \text{ (at error degree of freedom)}$$

Where,

S.E (d) = Standard error of difference

C.D. at 5% = Critical difference at 5 per cent level of significance

3.5.1.1 Variability estimation

In case of evaluation of different genotypes of *Andrographis paniculata*, the variability estimates for different characters along with coefficient of variability were calculated. The estimates consist of heritability, genetic advance and genetic gain were also carried out. Observations for variability, genetic estimates and correlation studies were limited to five selected plants in each replications. The components of genotypic, phenotypic and error variance were calculated as follows:

$$V_g = \frac{M_t - M_e}{R}$$

$$V_p = V_g + V_e$$

$$V_e = M_e$$

Where,

V_g = genotypic variance

V_p = phenotypic variance

V_e = error variance

3.5.1.2 Coefficient of variability

Phenotypic, genotypic and environmental coefficients of variability were carried out by formulae suggested by Burton and DeVane (1953).

$$\text{PCV (\%)} = \sqrt{\frac{V_p}{\bar{X}}} \times 100$$

$$\text{GCV (\%)} = \sqrt{\frac{V_g}{\bar{X}}} \times 100$$

$$\text{ECV (\%)} = \sqrt{\frac{V_e}{\bar{X}}} \times 100$$

Where,

PCV = phenotypic coefficient of variability

GCV = genotypic coefficient of variability

ECV = environmental coefficient of variability

\bar{X} = population mean of a particular character under study

3.5.1.3 Heritability

Heritability in percentage in broad sense was calculated by the formula suggested by Burton and De Vane (1953) and Johnson *et al.* (1955).

$$H (\%) = \frac{V_g}{V_p} \times 100$$

Where,

H = heritability in broad sense

V_p = phenotypic variance

V_g = genotypic variance

3.5.1.4 Genetic advance

The expected genetic improvement was calculated as per the formula suggested by Burton and De Vane (1953) and Johnson *et al.* (1955).

$$\text{Genetic advance} = \frac{V_g}{V_p} \times \sqrt{V_p} \times K$$

Where,

V_p = phenotypic variance

V_g = genotypic variance

K = selection difference at 5% selection intensity. The value of k is 2.06 (Allard, 1960)

3.5.1.5 Genetic gain

Genetic gain was also expressed in percent of population mean and was calculated by following method suggested by Johnson *et al.* (1955) as under:

$$\text{Genetic gain (\%)} = \frac{\text{Genetic advance}}{\bar{X}}$$

3.5.2 Correlation studies

If the change in one variable affects the change in the other variable, the variables are said to be correlated. In other words, the systematic interrelationship between the

variables is termed as correlation. The index of the degree of relationship between two continuous variables is known as correlation coefficient which can be calculated by following formula:

$$R = \frac{\text{Cov}(x, y)}{\sigma_x \cdot \sigma_y}$$

Chapter-4
Experimental Results

EXPERIMENTAL RESULTS

The present investigation entitled “**Evaluation of Kalmegh (*Andrographis paniculata*) Germplasm under Jammu Subtropics**” was conducted at Experimental Farm, Agroforestry, SKUAST Jammu, Chatha during kharif season of 2019-20. The data recorded on various parameters was analyzed and obtained is presented under different sub-headings with appropriate figures and table.

- 4.1 Mean performance of growth and yield attributes of different genotypes
- 4.2 Estimation of variability and genetic parameters
- 4.3 Correlation studies

4.1 Mean performance of growth and yield attributes of different genotypes

Fourteen genotypes of *Andrographis paniculata* procured from National Bureau of Plant Genetic Resources, New Delhi were evaluated for their effect on qualitative and quantitative parameters. From the analysis of variance, It is clear that accessions differed significantly from each other with respect to plant height (cm), number of branches per plant, plant spread (cm), number of leaves per plant, fresh herbage weight per plant (g), dry herbage weight per plant (g), fresh root weight per plant (g), dry root weight per plant (g) and estimated herbage yield (q ha⁻¹) except root-shoot ratio. The data of observed mean values of these characters is presented in Table 3&4 and results are described as under:

4.1.1 Plant height (cm)

From the data recorded, it was evident that the plant height varied significantly amongst all the accessions. The maximum plant height of 64.76 cm recorded in IC-622552 was statistically different from all other accessions. Accessions IC-622554 (60.27 cm), IC-622545 (59.47 cm) and IC-622549 (58.29 cm) were statistically at par with each other for this character. However, accession IC-622549 (58.29 cm) was statistically alike to IC-622548 (57.33 cm), IC-622555 (56.33 cm) and IC-622553 (56.30 cm). The data also

revealed that accession IC-622555 (56.33 cm) was also at par with plant height of 55.42 cm and 54.33 cm registered in accessions IC-622551 and IC-623182, respectively. Minimum plant height of 40.87 cm was recorded in accession IC-622544 but was statistical similar to accession IC-623172 (43.53 cm).

4.1.2 Number of branches per plant

Data in Table 3 indicated that there was a significant variation among the accessions for number of branches per plant. Maximum number of branches per plant observed in IC-622552 (17.26) was statistically alike to number of branches per plant recorded in accessions IC-622554 (16.74) and IC-622545 (15.96). However, accessions IC-622549 (14.21), IC-622548 (13.74), IC-622555 (13.21), IC-622553 (13.18) and IC-622551 (12.97) are all statistically at par with each other. Number of branches per plant of 11.86, 11.77, 11.01 and 10.04 recorded in IC-623182, IC-622550, IC-622547 and IC-622546, respectively are statistically alike. Minimum number of branches per plant (8.99) recorded in IC-622544 was at par with accessions IC-623172 (9.85) and IC-622546 (10.04).

4.1.3 Plant spread (cm)

Significant variation was found among different accessions for plant spread. Maximum plant spread of 47.27 cm was observed in accession IC-622552 followed by IC-622554 (44.48 cm) and both were statistically alike. From the data, it was revealed that accessions IC-622554 (44.48 cm), IC-622545 (43.68 cm) and IC-622549 (42.95 cm) were also statistically at par with each other. Accession IC-622548 (41.68 cm) was statistically alike to IC-622555 (40.42 cm) and IC-622553 (40.93 cm). Plant spread of 38.91 cm recorded in IC-622551 was also at par with plant spread of 37.75 cm and 37.12 cm observed in accessions IC-623182 and IC-622550, respectively. Minimum plant spread recorded in IC-622544 (27.54 cm) was at par with accession IC-623172 (29.44 cm) for this character.

4.1.4 Number of leaves per plant

A perusal of data revealed that the number of leaves per plant varied significant among all the accessions. Maximum number of leaves per plant (445.49) registered in

Table 3: Mean performance of growth parameters in different accessions of kalmegh

Accessions	Plant height (cm)	Number of branches plant⁻¹	Plant spread (cm)	Number of leaves plant⁻¹
IC-622544	40.87	8.99	27.54	262.84
IC-622545	59.47	15.96	43.68	414.56
IC-622546	48.45	10.04	32.85	284.07
IC-622547	51.33	11.01	35.08	299.49
IC-622548	57.23	13.74	41.68	354.85
IC-622549	58.29	14.21	42.95	374.45
IC-622550	53.33	11.77	37.12	308.48
IC-622551	55.42	12.97	38.91	329.27
IC-622552	64.76	17.26	47.27	445.49
IC-622553	56.3	13.18	40.93	339.74
IC-622554	60.27	16.74	44.48	424.34
IC-622555	56.33	13.21	40.42	342.59
IC-623172	43.53	9.85	29.44	279.09
IC-623182	54.33	11.86	37.75	318.18
CD_{0.05}	2.73	1.88	2.32	19.64

accession IC-622552 was significantly different from others. Accessions IC-622554 (424.34) and IC-622545 (414.56) were statistically alike for this character. Accession IC-622548 (354.85) was followed by IC-622555 (342.59) and IC-622553 (339.74), but all were statistically at par with each other. It was obvious from the data that accessions IC-623182 (318.18), IC-622550 (308.48), IC-622547 (299.49) were also statistically at par for this character. Minimum number of leaves of (262.84) recorded in accession IC-622544 was at par with (279.09) leaves recorded in accession IC-623172.

4.1.5 Fresh root weight per plant (g)

A perusal of data revealed that maximum fresh root weight per plant recorded in IC-622552 (8.54 g) was followed by IC-622554 (7.59 g), IC-622545 (7.44 g) and IC-622549 (7.23 g) whereas, all were statistically at par with each other. Accessions IC-622548 (7.01 g), IC-622555 (6.54 g), IC-622553 (6.48 g) and IC-622552 (6.28 g) were also statistically alike. Minimum fresh root weight per plant (3.97 g) registered in accession IC-622544 was at par with accessions IC-623172 (4.16 g), IC-622546 (4.63 g) and IC-622547 (4.98 g).

4.1.6 Dry root weight per plant (g)

Significant variation was found among different accessions for this character. Maximum dry root weight per plant of 4.02 g recorded in accession IC-622552 was statistically at par with accessions IC-622554 (3.46 g), IC-622545 (3.28 g), IC-622549 (3.07 g) and IC-622548 (2.99 g). Accessions IC-622549 (3.07 g), IC-622548 (2.99 g), IC-622555 (2.77 g), IC-633553 (2.60 g), IC-622551 (2.48 g), IC-623182 (2.36 g), IC-622550 (2.26 g) and, IC-623172 (1.98 g) were all statistically alike. Minimum dry root weight per plant (1.82 g) recorded in accession IC-622544 was at par with all the accessions except IC-622554 (3.46 g), IC-622545 (3.28 g), IC-622549 (3.07 g) and IC-622548 (2.99 g).

4.1.7 Fresh herbage weight per plant (g)

A critical analysis of data from Table 4 revealed that the maximum fresh herbage weight per plant of 87.43 g recorded in IC-622552 was significantly different from all

accessions. Accession IC-622554 with 77.64 g fresh herbage weight was statistically alike to accession IC-622545 (71.34 g). However, accessions IC-622548, IC-622555, IC-622553 and IC-622551 with fresh herbage weight of 64.38 g, 61.96 g, 60.86 g, 58.35 g, respectively were also at par with each other. Accessions IC-622551 (58.34 g), IC-623182 (57.15 g), IC-622550 (54.51 g) and IC-622547 (52.96 g) were also at par with each other. The lowest fresh herbage weight per plant was found in accession IC-622544 with (45.04 g) but was at par with accessions IC-623172 (46.94 g) and IC-633546 (49.95 g).

4.1.8 Dry herbage weight per plant (g)

Significant variation was found among different accessions for dry herbage weight per plant. Maximum dry herbage weight per plant was registered in accession IC-622552 (42.41 g) followed by IC-622554 (39.25 g) but both were statistically alike with each other. Dry herbage yield per plant of 33.14 g, 31.76 g, 29.45 g registered in accessions IC-622545, IC-622549, IC-622548, respectively was statistically at par with each other. However, accessions IC-622555 (26.36 g), IC-622553 (25.96 g), IC-622551 (24.01 g) and IC-623182 (23.07 g) were also statistically alike for this character. Minimum dry herbage weight per plant of 16.54 g observed in IC-622544 was statistically at par with IC-623172 (17.96 g) and IC-622546 (19.32 g).

4.1.9 Root shoot ratio

A perusal of the data showed that the accessions did not differ significantly among themselves for root shoot ratio. However, maximum root shoot ratio was observed in accessions IC-622544 (0.115) followed by IC-623172 (0.112). Minimum root-shoot ratio of (0.089) was found in accession IC-622554.

4.1.10 Estimated dry herbage yield (q ha⁻¹)

A critical analysis of data revealed that there is a significant variance among all the accession in dry herbage yield. Maximum dry herbage yield of 31.41 q ha⁻¹ recorded in accession IC-622552 was statistically at par with dry herbage yield observed in accession IC-622554 (29.07 q ha⁻¹). Accessions IC-622545 (24.55 q ha⁻¹), IC-622549 (23.52 q ha⁻¹) and IC-622548 (21.81 q ha⁻¹) were statistically alike for this parameter. However,

Table 4: Mean performance of yield parameters in different accessions of kalmegh

Accessions	Fresh root weight plant⁻¹ (g)	Dry root weight plant⁻¹ (g)	Fresh herbage weight plant⁻¹ (g)	Dry herbage weight plant⁻¹ (g)	Root-shoot ratio	Estimated dry herbage yield (q ha⁻¹)
IC-622544	3.97	1.89	45.04	16.54	0.115	12.25
IC-622545	7.44	3.28	71.34	33.14	0.099	24.54
IC-622546	4.63	2.09	49.95	19.32	0.108	14.31
IC-622547	4.98	2.17	52.96	20.96	0.104	15.52
IC-622548	7.01	2.99	64.28	29.45	0.101	21.81
IC-622549	7.23	3.07	68.49	31.76	0.097	23.52
IC-622550	5.48	2.26	54.51	21.64	0.104	16.02
IC-622551	6.28	2.48	58.34	24.01	0.102	17.38
IC-622552	8.54	4.02	87.43	42.41	0.095	31.41
IC-622553	6.48	2.60	60.84	25.96	0.100	19.22
IC-622554	7.59	3.46	77.64	39.25	0.089	29.07
IC-622555	6.54	2.77	61.96	26.36	0.106	19.49
IC-623172	4.16	1.98	46.94	17.96	0.112	13.30
IC-623182	5.95	2.36	57.15	23.07	0.102	17.08
CD_{0.05}	1.39	1.09	6.73	3.79	NS	2.78

*NS- Non-significant

accessions IC-622548 (21.81 q ha⁻¹), IC-622555 (19.49 q ha⁻¹) and IC-622553 (19.22 q ha⁻¹) were also statistically at par with each other. Accessions IC-622551 (17.38 q ha⁻¹), IC-623182 (17.08 q ha⁻¹), IC-622550 (16.02 q ha⁻¹) and IC-622547 (15.52 q ha⁻¹) were also statistically at par with each other. Minimum herbage yield (12.25 q ha⁻¹) was recorded in accession IC-622544 and the yield was at par with yield recorded in accessions IC-623172 (13.30 q ha⁻¹) and IC-622546 (14.31 q ha⁻¹).

4.2 Estimation of variability and genetic parameters

Variability estimates were worked out with respect to general mean, range, variance and coefficient of variability. Genetic parameters were estimated in terms of heritability, genetic advance and genetic gain. The various results obtained are tabulated in Table 5 and are described as under:

The estimate of coefficient of variation (GCV and PCV) were found to be higher for estimated dry herbage yield followed by dry herbage yield per plant.

Higher assessment of heritability were noticed for the characters particularly for number of leaves per plant followed by plant spread, plant height, estimated dry herbage yield, dry herbage yield and fresh herbage yield per plant.

The highest estimates of expected genetic advance was recorded for number of leaved per plant. Highest genetic gain was recorded for estimated dry herbage yield followed by dry herbage yield per plant and fresh herbage weight per plant.

The character-wise descriptions are represented below:

4.2.1 Plant height (cm)

The overall mean for plant spread was 54.28 cm, with a minimum and maximum value of 40.87 cm (IC-622544) and 64.76 cm (IC-622552), respectively. The coefficient of variability of 11.82 per cent and 12.18 per cent was recorded at genotypic and phenotypic levels, respectively. Heritability estimate was 94.03 per cent which was accompanied by genetic advance of 12.81 per cent and genetic gain of 23.60 per cent.

4.2.2 Number of branches per plant (g)

The overall average of the trait was 12.91 with a range of 17.26 (IC-622552) - 8.99 (IC-622544). The character showed the genotypic coefficient of variability of 19.09 per cent and phenotypic coefficient of variability of 20.95 per cent. Heritability of 83.04 per cent with genetic advance of 4.62 per cent and genetic gain of 75.41 per cent was recorded for this character.

4.2.3 Plant spread (cm)

The mean number of plant spread per plant was 38.58 cm with the range of 47.27 cm (IC-622552) - 27.54 cm (IC-622544). Coefficient of variability at genotypic and phenotypic levels were recorded to be 14.72 per cent and 15.14 per cent, respectively. Heritability of 94.60 per cent with genetic advance of 11.37 per cent and genetic gain of 29.47 per cent was recorded.

4.2.4 Number of leaves per plant

The range observed for number of leaves per plant was 445.49 (IC-622552) - 262.84 (IC-622544) with a mean value of 341.25. Genotypic and phenotypic coefficient of variability were of the order of 16.38 per cent and 16.73 per cent, respectively. Heritability estimates of 95.84 per cent along with genetic advance of 112.74 per cent and genetic gain of 33.04 per cent was recorded for this character.

4.2.5 Fresh root weight per plant (g)

Fresh root weight per plant varied between 8.54 g (IC-622552) and 3.97 g (IC-622544) with the mean value of 6.16 g. The coefficient of variability was of the order of 20.89 per cent and 24.81 per cent at genotypic and phenotypic levels, respectively. Heritability estimates was of the order of 70.92 per cent along with genetic advance of 2.23 per cent and genetic gain of 36.24 per cent.

4.2.6 Dry root weight per plant (g)

The average value of dry root weight per plant was 2.62 g with the maximum and minimum values of 4.02 g (IC-622552) and 1.89 g (IC-622544), respectively. The

Table 5: Estimates of variability and genetic parameters for different characters

Character	Range	Mean	Coefficient of variability		Heritability (%)	Genetic Advance (%)	Genetic gain (%)
			Genotypic (%)	Phenotypic (%)			
Plant height (cm)	64.76-40.87	54.28	11.82	12.18	94.03	12.81	23.60
Number of branches plant ⁻¹	17.26-8.99	12.91	19.09	20.95	83.04	4.62	35.84
Plant spread (cm)	47.27-27.54	38.58	14.72	15.14	94.60	11.37	29.47
Number of leaves plant ⁻¹	445.49-262.84	341.25	16.38	16.73	95.84	112.74	33.04
Fresh root weight plant ⁻¹ (g)	8.54-3.97	6.16	20.89	24.81	70.92	2.23	36.24
Dry root weight plant ⁻¹ (g)	4.02-1.89	2.67	18.69	30.58	37.34	0.63	23.54
Fresh herbage weight plant ⁻¹ (g)	87.43-45.04	60.99	19.18	20.30	89.27	22.77	37.33
Dry herbage yield plant ⁻¹ (g)	42.41-16.54	26.56	28.99	30.2	92.17	15.23	57.33
Estimated dry herbage yield (q ha ⁻¹)	31.41-12.25	19.67	29	30.19	92.30	11.29	57.40

coefficient of variability were of the order of 18.69 per cent and 30.58 per cent at genotypic and phenotypic levels, respectively. The heritability was estimated to be 37.34 per cent with genetic advance and genetic gain of 0.63 per cent and 23.54 per cent, respectively.

4.2.7 Fresh herbage weight per plant (g)

The overall average of fresh herbage weight per plant was 60.99 g with the observed range of 87.43 g (IC-622552) - 45.04 g (IC-622544). The genotypic and phenotypic coefficients of variability were of the order of 19.18 per cent and 20.30 per cent, respectively. The heritability was estimated to be 89.27 per cent with genetic advance and genetic gain of 22.77 per cent and 37.33 per cent, respectively.

4.2.9 Dry herbage weight per plant (g)

The range observed for dry herbage weight per plant was 42.41 g (IC-622552) - 16.54 g (IC-622544) with the average of 26.56 g. The genotypic and phenotypic coefficient of variability was recorded to be 28.99 per cent and 30.20 per cent, respectively. The heritability was estimated to be 92.17 per cent with genetic advance of 15.23 per cent and genetic gain of 57.33 percent.

4.2.10 Estimated dry herbage yield (q ha⁻¹)

Estimated dry herbage yield varied between 31.41 q ha⁻¹ (IC-622552) -12.25 q ha⁻¹ (IC-622544) with a mean value of 19.67 q ha⁻¹. For this character, coefficients of variability at genotypic and phenotypic levels were recorded to be 29.00 per cent and 30.19 per cent, respectively. The heritability was estimated to be 92.30 per cent with genetic advance of 11.29 per cent and genetic gain of 57.40 per cent.

4.3 Correlation studies

Correlation study facilitates simultaneous improvement of two or more characters. Knowledge of relationship among yield components is essential for the formulation of breeding programmes aimed at achieving the desirable combination of various components of yield. The essence of interrelation between different characters has been carried out by calculating correlation coefficient which are presented in the Table 6.

In the present study, correlation coefficient for different traits were significant for all the characters indicating interrelationship between various characters. The exploration of the data presented in Table 6 revealed that dry herbage yield weight per plant was positively and significantly correlated with all the parameters.

Highly significant positive correlation has been observed for traits pairs fresh herbage weight per plant vs dry herbage weight per plant (0.966), plant spread vs plant height (0.949), dry herbage weight per plant vs number of leaves per plant (0.934), fresh herbage weight per plant vs no of leaves per plant (0.932), number of leaves per plant vs number of branches per plant (0.910), dry herbage weight per plant vs number of leaves per plant (0.901), plant spread vs number of leaves per plant (0.898), fresh herbage weight per plant vs number of branches per plant (0.889), number of leaves per plant vs plant height (0.886), plant spread vs no of branches per plant (0.880), fresh herbage weight per plant vs plant height (0.876), dry herbage weight per plant vs plant height (0.873), fresh herbage weight per plant vs plant spread (0.873), number of branches per plant vs plant height (0.854), fresh root weight per plant vs plant spread (0.848), dry herbage weight per plant vs plant height (0.847), fresh root weight per plant vs plant height (0.842), fresh root weight per plant vs number of leaves per plant (0.841), fresh root weight per plant vs number of branches per plant (0.836), dry herbage weight per plant vs fresh root weight per plant (0.808), fresh herbage weight per plant vs fresh root weight per plant (0.805), dry root weight per plant vs number of leaves per plant (0.753), dry herbage weight per plant vs dry root weight per plant (0.718).

Moderately significant correlation has been observed for trait pairs viz. fresh herbage weight per plant vs dry root weight per plant (0.694), dry root weight per plant vs fresh root weight per plant (0.675), dry root weight per plant vs plant height (0.674), dry root weight per plant vs number of branches per plant (0.654), dry root weight per plant vs plant spread (0.631).

Table 6: Correlation between different growth and yield parameters

Characters	Plant height (cm)	Number of branches plant⁻¹	Number of leaves plant⁻¹	Plant spread (cm)	Fresh root weight plant⁻¹	Dry root weight plant⁻¹	Dry herbage weight plant⁻¹	Fresh herbage weight plant⁻¹
Plant height	1							
Number of branches per plant	0.854**	1						
Number of leaves per plant	0.886**	0.910**	1					
Plant spread	0.949**	0.880**	0.898**	1				
Fresh root weight per plant	0.842**	0.836**	0.841**	0.848**	1			
Dry root weight per plant	0.674**	0.654**	0.753**	0.631**	0.675**	1		
Dry herbage weight per plant	0.847**	0.901**	0.934**	0.873**	0.808**	0.718**	1	
Fresh herbage weight per plant	0.876**	0.889**	0.932**	0.873**	0.805**	0.694**	0.966**	1

**Significant at 1% level

Chapter-5

Discussion

DISCUSSION

Plants for the purpose of medicine have been used since ancient times to heal and cure diseases and to improve the health of human beings. According to the World Health Organization (WHO), the goal of “Health for All” can’t be achieved without herbal medicines. India exports herbal materials and medicines to the tune of nearly 600 crores annually. About 960 species of medicinal plants are estimated to be in trade of which 178 species have annual consumption levels in excess of 100 metric tonnes (Planning Commission, 2011).

Use of the medicinal plants is a core component at primary healthcare level due to availability, acceptability, compatibility and affordability. Dependency on these medicinal plants varies from country to country. It is estimated that about 75–80% of people of developing countries and about 25% of people of developed countries depend either directly or indirectly on medicinal plants for the first line of treatment. Therefore, people are encouraging indigenous production and processing of these medicinal plants to use in different cultures and religion for the treatment of various diseases.

Keeping in view, the present status of medicinal plants, it is desirable that appropriate strategies and techniques are developed to conserve the existing germplasm and propagate it on a commercial basis. Production of official parts through cultivation not only sustains the supply of raw materials to pharmaceutical industry but also conserve their population in nature.

Among various medicinal plants in demand, kalmegh also has high demand with in the country as well as in abroad. Kalmegh is one of the most important kharif seasonal medicinal plants which is a boon for weaker section of rural areas and plays an important role for their income generation. It is in prioritized list of medicinal plants identified by the National Medicinal Plant Board, New Delhi and is eligible for 30 per cent subsidy under “National Ayush Mission”. It has an important place in India pharmacopoeia and is being prominently used in 26 ayurvedic formulae.

To augment the production of kalmegh, it is mandatory to increase the yield of its economic parts. The present investigation has been undertaken with the objectives of evaluating different accessions of *Andrographis paniculata* to identify the better genotypes. The result obtained during the present investigation on “**Evaluation of Kalmegh (*Andrographis paniculata*) Germplasm under Jammu Subtropics**” have been discussed in the presence of available literature as under:

5.1 Evaluation of different accessions of *Andrographis paniculata* for growth and yield parameters

One of the most important approaches to increase the yield of medicinal plants lies with developing suitable strain by selecting genetically superior lines among the existing population. Cultivation of superior genotypes/high yielding will help in reducing pressure upon the natural resources besides meeting need of pharmaceutical industries.

Andrographis paniculata is one such important species used as a raw material in traditional and modern pharmaceutical industries. In India, it is mainly found at an altitudes of 400-900m in the states of Andhra Pradesh, Assam, Bihar, Karnataka, Kerala, Madhya Pradesh, West Bengal, tarai region of Uttar Pradesh and in Haridwar and Dehradun areas of Uttarakhand. Because of the variation occurring in climatic and soil conditions at different ecological niches in different states, there is a great deal of variation in growth and yield parameters vis-à-vis accumulation of active ingredient in its official parts.

In this experiment, fourteen accession of *Andrographis paniculata* were procured from National Bureau of Plant Genetic resources, New Delhi to characterize and evaluate for growth and yield parameters.

5.1.1 Mean performance of growth and yield parameters of different accessions

The main aim of evaluation of different genotypes is to determine inherent differences among different varieties and manipulate them in desired direction to obtain good result. The observed value of traits measured on an individual is the phenotypic value of that individual. This value is partly due to genes which the individual receives from its parents and partly due to the environment in which it is raised. Exposition of Tables 3 and

4 revealed significant variation among the fourteen accessions of *Andrographis paniculata* on the basis of mean performance of all the characters. The mean performance of trait help to identify the superior genotype among the existing populations. The mean performance also serves as a primary criterion for selection of desirable plants (Kumar *et al.*, 1979).

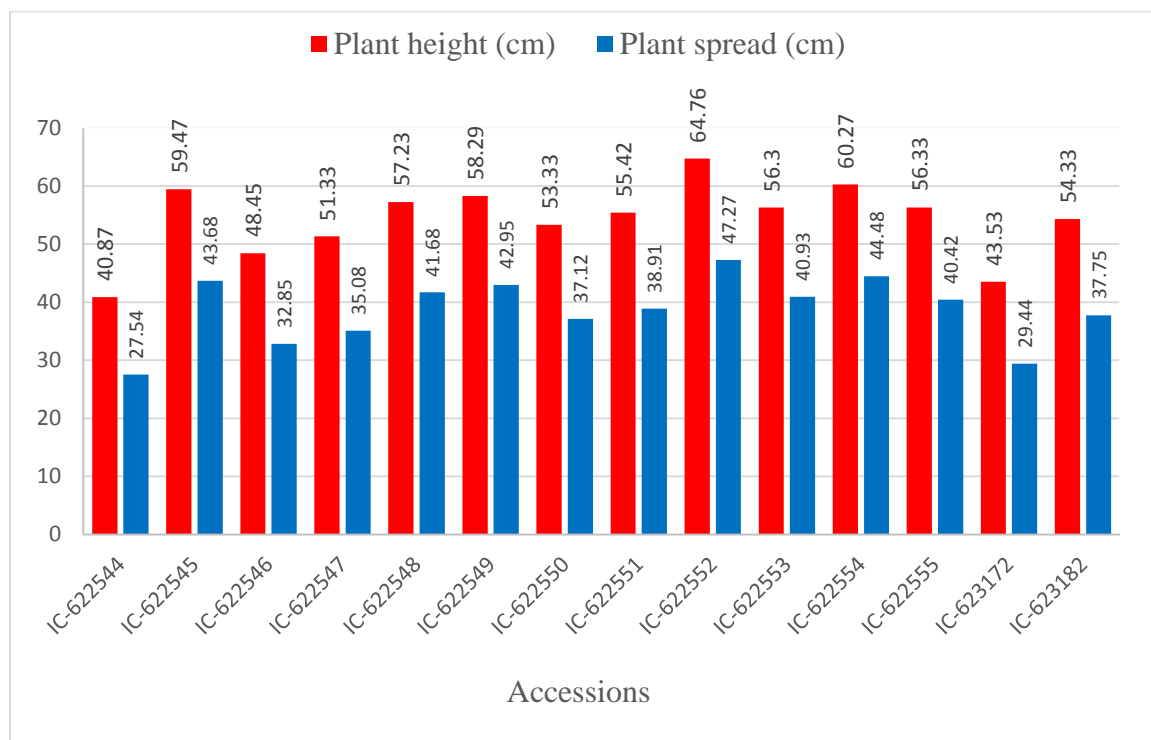


Fig. 5 Plant height and plant spread in different accessions of kalmegh

Among the fourteen accessions evaluated, IC-622552 recorded the highest significant value (64.76 cm) for plant height which was followed by the accessions IC-622554 (60.27 cm) and IC-622545 (59.47 cm). Lowest plant height was recorded in IC-622544 (40.87 cm) (Fig.1). Hemalatha and Suresh, (2012) have also reported a similar range of plant height (56.54 cm- 42.96 cm) in their study on kalmegh at Horticultural College and Research Institute, Periyakulam. The higher values of number of branches per plant were also reported in the accession IC-622552 (17.26) followed by IC-622554 (16.74), while the minimum of branches was recorded in (8.99). Number of branches per plant recorded are in line with experiment conducted at NDUAT, Faizabad where the maximum of 22.50 branches per plant and the minimum of 10.40 branches were recorded in the entry AICRP-MAPB-120-122 of kalmegh (DMAPR, 2013). The maximum number

of leaves per plant was recorded in IC-622552 (445.49) followed by IC-622554 (424.34) and IC-622545 (414.56). However, minimum number of leaves per plant was registered in IC-622544 (262.84). These are in conformity with the early finding of Liphan and Detpirtmongkol (2017) wherein, range of 469-212 leaves per plant was recorded in different genotypes of kalmegh. Lattoo *et al.* (2008) also observed a range of 216.6-419 leaves per plant in kalmegh while screening different genotypes of kalmegh.

Accession IC-622552 recorded the highest value (47.27 cm) for plant spread which was followed by IC-622554 (44.48 cm). Minimum plant spread was observed in accession IC-622544 (27.54 cm) (Fig.4). Semwal *et al.*, (2016) also recorded a similar observation on plant spread with the range of 47.10 cm to 38.40 cm in kalmegh while conducting experiment on different planting geometry. Similar result with highest value of plant spread with 47.23 cm and minimum value 38.63 cm was registered in experiment on genotypic evaluation of kalmegh at Faizabad (DMAPR, 2017). Accession IC-622552 recorded the highest fresh herbage weight per plant (87.43 g) which was followed by IC-622554 (77.64 g), while the minimum fresh herbage yield was obtained in accession IC-622544 (45.04 g). Dry herbage yield per plant recorded highest in accessions IC-622552 (42.41 g) and IC-622554 (39.25 g) while the lowest was observed in the accession IC-622544 (16.54 g) (Fig. 5). These result are in contradiction with the finding of Pandey and Mandal (2010) who have reported lower range of fresh herbage weight per plant and dry herbage weight per plant of 64.80-58.30 g and 18.92-16.58 g, respectively. This may be due to climatic variation at two places. However, the fresh and dry herbage yield per plant recorded in the present study are in conformity with earlier reports of Lattoo *et al.*, 2008; DMAPR, 2013 and Devi *et al.*, 2017.

Dry herbage yield per hectare in present study is in the range of 12.25-31.41 q ha⁻¹, highest being recorded in accessions IC-622552 followed by IC-622554 while, the lowest in accessions IC-622544 (Fig. 5). The yield observed is within the range of 6.64-42.55 q ha⁻¹ and is in line with reports by DMAPR, (2014); Raina *et al.* (2013); Hemalatha and Suresh (2012) and DMAPR, (2012).

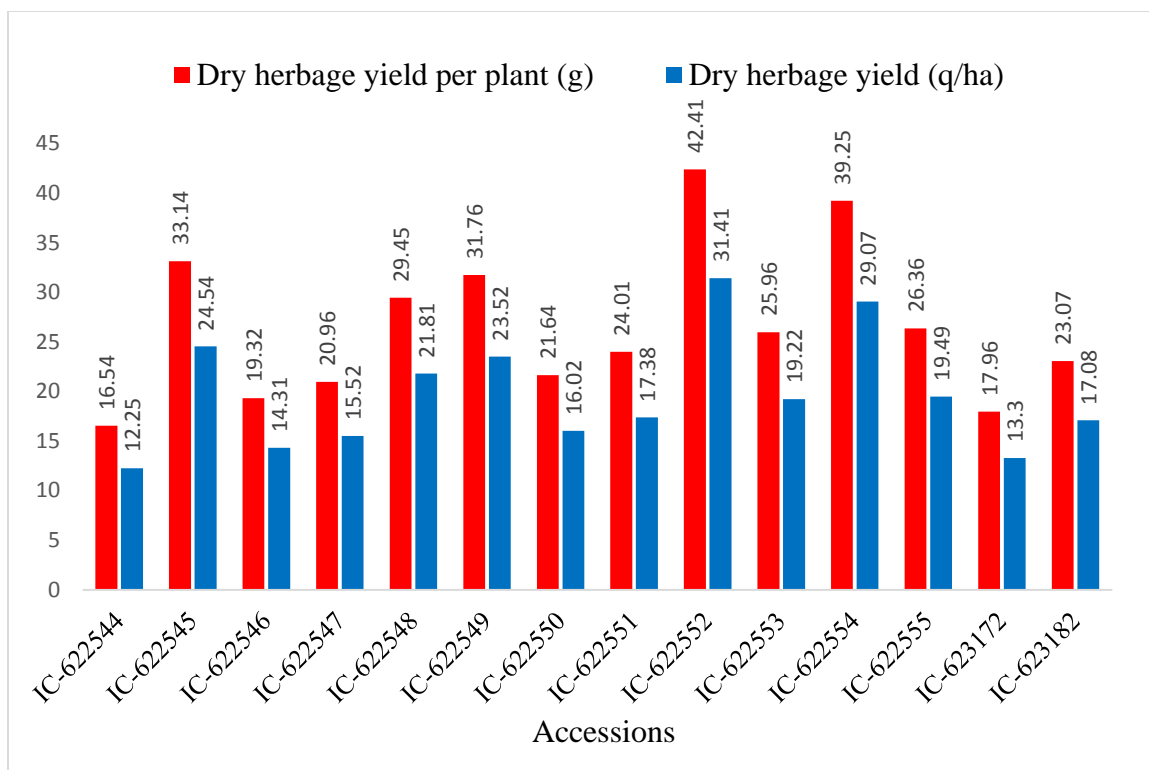


Fig. 6 Dry herbage yield of different accessions of kalmegh

5.1.2 Estimate of variability and genetic parameters

Variability refers to the observed differences with in population for a particular genotypes or any trait. These differences may be partly due to genetic cause and partly due to environment trapping. The combined expression of both of these is the phenotype effect. Observed value of an individual appraised trait is the phenotypic values of the individual. Genetic variability is the gift of nature and its fruitful utilization calls for systematic collection, evaluation, description and grouping based on economic descriptors. Use of crop genetic resources in crop improvement programme is the ultimate objective of germplasm resource management and improvement in both qualitative and quantitative characters of a crop should be the main aim of any breeding programmes (Simmonds, 1962). The main objective of crop improvement and breeding programme is to screen out the best cultivar of medicinal and aromatic plants germplasm based upon bio-chemical parameters for particular climatic and edaphic conditions.

Genotypic and phenotypic coefficients of variation are simple measure of variability and these measures are commonly used for the assessment of variability. The relative value of these types of coefficients gives an idea about the magnitude of variability present in a genetic population of any given species (Jain, 1982). Thus, the component of variation such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are computed. Heritability governs the resemblance between parents and their progeny whereas, the genetic advance provide the knowledge about expected gain for a particular character after selection. Heritability suggests the relative role of genetic factors in expression of phenotypes and also acts as an index of transmissibility of a particular trait to its offspring. Heritability estimate and provide the information regarding the amount of transmissible genetic variation to total variation and determine genetic improvement and response to selection. Heritability estimate along genetic advance are normally more useful in predicting the gain under selection than that of heritability alone. Heritability components comprises of additive and non-additive and it is the former which respond to selection (Wright 1921). Genetic improvement of any crop largely depend on the magnitude of several genetic parameters like analysis of variance of each mean value, phenotypic and genotypic variance, phenotypic and genotypic coefficient of variation (PCV and GCV), heritability, genetic advance and genetic gain on which the breeding methods are formulated for its further improvement. Therefore, the knowledge of all the parameters of variability is very useful for the development of superior genotypes with high yielding varieties.

The results obtained in the current study for different characters with regards to variability parameters express that mean values have a wider range suggesting the presence of good amount of variability. Higher value of genotypic coefficient of variation and phenotypic coefficient of variation was obtained for dry herbage yield per plant, estimated dry herbage yield, fresh herbage weight plant, number of branches per plant and fresh root weight per plant which indicates that the substantial variability existing for this characters with greater scope of selection for better expression. Devi *et al.* (2017) have also reported high genotypic and phenotypic variation for dry herbage yield and fresh herbage yield in kalmegh. However, the phenotypic coefficients of variation are on the slightly higher side than the genotypic coefficients of variation indicating light influence of environment in the

expression of the character viz. plant height (cm), number of branches per plant, fresh herbage weight per plant (g), dry herbage weight per plant (g), fresh root weight per plant (g), dry root weight per plant (g) and estimated herbage yield. On the other hand, plant height, plant spread and number of leaves per plant registered the low GCV and PCV. Manjesh *et al.* (2016) also found the lower values of GCV and PCV for plant height, number of branches per plant and plant spread in kalmegh.

Heritability and genetic advance estimate provide the information regarding the amount of transmissible genetic variation to total variation and determine genetic improvement and response to selection. In the present investigation, higher heritability was observed for number of leaves per plant, plant spread, plant height, dry herbage yield ($q\text{ ha}^{-1}$), dry herbage yield per plant, fresh herbage yield per plant and number of branches per plant. Higher heritability observed for these characters might be due to additive effects and selection pressure could be profitably applied on these characters for yield improvement. Johnson *et al.* (1955) observed that heritability estimates along with genetic gain is more useful information than the heritability alone in predicting the final effect for selecting the best genotypes. Higher genetic gain is registered in dry herbage yield per hectare (q), dry herbage yield per plant, fresh herbage weight per plant, fresh root weight per plant, number of branches per plant, number of leaves per plant and plant spread thus can safely be considered for obtaining more of genetic improvement in population through selection.

5.1.3 Correlation studies

The knowledge of relationship of various characters among themselves is most important for any programme of tree improvement. Yield is a complex trait whose production is influenced by its component traits directly or indirectly. Breeder is certainly interested in investigating the extent and type of association of such traits for they contribute valuable information in breeding for yield. Knowledge of the association of yield and its components traits will enable him to know how the selection pressure exerted by him on one trait will cause changes in other traits. Thus of the association between yield and its components is crucial in breeding for a certain crop. Correlation is used for the purpose of quantification of relationships among traits in crop plants. The biometric tool “correlation” indicates the intensity and direction of association of a character with yield.

An appraisal of the result revealed that the correlation coefficients were worked out for all the characters and the combination were positively and significantly correlated with each other. Dayana *et al.* (2018) have also reported positive significant correlation of total dry weight per plant with number of leaves at harvest, leaf dry weight and stem dry weight per plant.

In the present investigation, highly significant positive correlation has been observed for dry herbage weight per plant with plant height, number of branches per plant, plant spread, fresh root weight per plant, dry root weight per plant and fresh herbage weight per plant, thus suggesting that these characters are important yield components and the effective improvement in yield can be achieved through selection based on these characters. However, majority of these characters have also high heritability coupled with good genetic gain value, thus indicating additive genetic nature of the heritable component present in them. Therefore, selection for these traits would bring about desirable improvement in the species under study for dry herbage yield.

Chapter-6

Summary and Conclusions

SUMMARY AND CONCLUSIONS

The present study entitled “**Evaluation of Kalmegh (*Andrographis paniculata*) Germplasm under Jammu Subtropics**” was conducted at Experimental Farm of Division of Agroforestry, Sher-e-Kashmir university of Agricultural Sciences and Technology, Chatha, Jammu. The basic purpose of this study was to study the performance of kalmegh under Jammu subtropics and to identify superior accessions for the region. Identification of superior accessions among the existing population is a key parameter to increase its yield. Keeping this in mind, the present investigations was conducted to evaluate the different accessions for growth and yield parameters. This experiment was conducted with 14 accessions under Randomized Block Design with three replication in each. The salient features for the investigation are summarized below:

Fourteen accessions of kalmegh (*Andrographis paniculata*) obtained from National Bureau of Plant Genetic resources, New Delhi formed the base material to study the growth performance and to find out variability among them. From the analysis of variance, it is evident that the accessions differed significantly for growth and yield parameters. Dry herbage weight plant⁻¹, Fresh herbage weight plant⁻¹ and plant spread varied from 42.41-16.54 g, 87.43-45.04 g and 47.27-27.54 cm, respectively. Higher dry herbage yield per hectare (q) was observed in accession IC-622552 (31.41 q ha⁻¹) and IC-622554 (29.07 q ha⁻¹).

The analysis of variance also showed a wide range of variability in the range of most of the growth and yield parameters viz. number of leaves per plant (445.49-262.84), plant height (64.76-40.87 cm), fresh herbage weight per plant (87.43-45.04 g), dry herbage yield per plant (42.41-16.54 g), dry herbage yield per hectare (31.41-12.25 q) with mean value of 341.25, 54.28 cm, 60.99 g, 26.56 g and 19.67 q ha⁻¹ recorded for number of leaves per plant, plant height, fresh herbage weight per plant, dry herbage yield per plant and dry herbage yield per hectare (q), respectively . The values for genotypic coefficient of variability and phenotypic coefficient of variability were higher for characters dry herbage

yield per plant (28.99%, 30.20%), dry herbage yield per hectare (q) (29.00%, 30.19%), fresh herbage weight per plant (19.18%, 20.30%), fresh root weight per plant (20.89%, 24.81%) and number of branches per plant (19.09%, 20.95%), respectively. Whereas, lowest estimates of GCV and PCV was recorded in plant height (11.82%, 12.18%), respectively. Highest estimates of heritability was observed for number of leaves per plant (95.84%), plant spread (94.60%), plant height (94.03%), estimated dry herbage yield (92.30%), dry herbage yield per plant (92.17%), fresh herbage yield per plant (89.27%) which indicates that these characters can be easily improved through selection. High estimates of genetic advance and genetic gain was recorded for number of leaves per plant and dry herbage yield per hectare, respectively. All the characters and combination were positively and significantly correlated with each other. Highly significant values are observed for the trait pairs fresh herbage weight per plant vs. dry herbage weight per plant (0.966), plant spread vs plant height (0.949), dry herbage weight per plant vs number of leaves per plant (0.934), fresh herbage weight per plant vs number of leaves per plant (0.932), number of leaves per plant vs number of branches per plant (0.910), dry herbage weight per plant vs number of branches per plant (0.901), plant spread vs number of leaves per plant (0.898) while, the moderate significant values are observed in trait pairs of dry root weight per plant vs number of branches per plant (0.654) and dry root weight per plant vs plant spread (0.631).

CONCLUSION

- Out of fourteen accessions, accession IC-622552 and IC-622554 are superior over others resulting in higher dry herbage yield.
- Higher heritability along with high genetic gain was observed for number of leaves per plant, number of branches per plant, fresh herbage yield per plant and dry herbage yield per plant which indicate sufficient potential for improvement in the species through selection for these traits.

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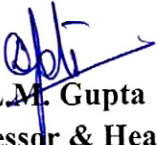
CERTIFICATE-IV

Certified that all the necessary corrections as suggested by the external examiner and the Advisory committee have been duly incorporated in the thesis entitled “Evaluation of Kalmegh (*Andrographis paniculata*) Germplasm under Jammu Subtropics” submitted by Mr. Aatish Kumar Sharma, Registration No. J-18-M-564.


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