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Research Article

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Performance of African marigold (*Tagetes errecta*) cultivars for vegetative, flower and chemical traits at different locations of Ethiopia

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ABSTRACT

Despite the African marigold (*Tagetes erecta* L.) is one of the most commercially exploited flower and medicinal crops in the world and have received great attention in scientific research in the recent past, the plant has never been tested under Ethiopian condition for its agronomic and chemical traits. Thus, the present study was conducted with the main objective to evaluate the growth, yield and quality attributes of three introduced African marigold cultivars. The experiments were conducted at six locations in Ethiopia using a randomized complete block design with three replications. Data on vegetative growth, flower characteristics, inflorescence yield, and xanthophyll content were collected and statistically tested. Significant variation ($P < 0.01$) was observed among cultivars across the tested locations for all the studied parameters. Overall higher values of plant height (65.48 cm), branch number plant^{-1} (89.09), inflorescence number plant^{-1} (76.89), inflorescence weight (25.48 g), inflorescence yield plant^{-1} (560.77 g) and inflorescence yield ha^{-1} (18 t) were obtained in AVT001 cultivar and flower xanthophyll content (27.6 mg g^{-1}) in AVT540 cultivar; while lowest values were rerecorded for all characters in Hewoyde cultivar. Inflorescence yield ha^{-1} was found positively and significantly correlated with all parameters except xanthophyll content. Xanthophyll content was found positively and significantly correlated with flower weight. As the cultivars AVT001 and AVT540 are adapted very well and gave comparable and/or higher yields with the other marigold growing countries, the two cultivars can be recommended for commercial cultivation of their inflorescence and extracted pigments in Ethiopia.

KEYWORDS: African marigold, Medicinal herb, Natural colorant, Ornamental horticulture, Xanthophyll content

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INTRODUCTION

African marigold (*Tagetes erecta* L.) is one of the commercially exploited flowers occupying a prominent place in ornamental horticultural plants belonging to the family Asteraceae (Singh *et al.*, 2017; Mir *et al.*, 2019). It is an annual herb, erect, highly branching, growing up to 1.4 m (Aslam *et al.*, 2016; Srinivas & Rajasekharam, 2020), and produces large flowers ranging from yellow to orange (Mir *et al.*, 2019; Singh *et al.*, 2019). It is native to Central and South America especially Mexico (Idan *et al.*, 2014). It is widely cultivated in Europe, the USA, China, India, the Caribbean, Africa and Oceania (Davidse *et al.*, 2018). It prefers a nourishing soil of pH 7.0 to 7.5 with good water-holding capacity and well-drained fertile sandy loamy soil as well as a sunny climate (Davidse *et al.*, 2018; Priyadarshini *et al.*, 2018).

African marigold is widely cultivated as bedding plants, loose flower, insect and nematode repellents, and nutrient supplement for poultry feed (Becerra *et al.*, 2020; Pandey *et al.*, 2021). Its flower juice is given as a remedy for bleeding piles (Verma & Verma, 2012; Dasgupta *et al.*, 2016). African marigold is cultivated commercially as an important source of fat-soluble carotenoid pigments extracted from its flowers (Ahmad *et al.*, 2017; Mir *et al.*, 2019). The principal component of the carotenoid is xanthophyll pigments (natural dyes) (Mir *et al.*, 2019; Becerra *et al.*, 2020). About 70 to 90% of the xanthophyll pigment is lutein (Sowbhagya *et al.*, 2014; Lin *et al.*, 2015). The carotenoids extracted from the flowers are used as a natural food additive to brighten egg yolks and poultry feathers (Becerra *et al.*, 2020). Xanthophyll is known to prevent cancer and improve immune function (Hadden *et al.*, 1999). Lutein, extracted from xanthophyll, plays an important role in the prevention of cancer and central retina degradation (Sandmann, 2015; Becerra *et al.*, 2020). It is fat-soluble carotenoid pigments have been extensively used effectively to dye fabrics commercially (Lin *et al.*, 2015; Yusuf *et al.*, 2017; Elsahida *et al.*, 2019).

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As described in Becerra *et al.* (2020) the annual global market for carotenoids has been increasing at the rate of 5.7% during 2017 (1400 million US$) and 2022 (2000 million US$). The global demand for natural dyes has been growing at a CAGR of 11% and is expected to generate revenue of about 5 billion USD by 2024 (GlobeNewswire, 2020). At present, the supply of natural dyes is only 1% of the 10,000 tons of the global market demand (Senthilkumar *et al.*, 2015; Elsahida *et al.*, 2019), which indicates an excessive use of synthetic dyes. Currently, ecological considerations are becoming important factors in the selection of consumer goods all over the world (Elsahida *et al.*, 2019). By the early part of this century, only a small percentage of textile dyes were extracted from plants, but now, there has been increasing interest in natural dyes, as the public has become aware of ecological and environmental problems related to the use of synthetic dyes. The rise in global demand for its flower and processed products (Elsahida *et al.*, 2019; Becerra *et al.*, 2020) as well as the existence of conductive investment climates in Ethiopia has attracted the interest of investors for the large-scale cultivation of African marigolds in the country. However, as far as our knowledge is concerned, African marigolds have never been evaluated for their vegetative, flower characteristics, flower yield and quality aspects in Ethiopia, which is endowed with diverse agro-climatic conditions (National Metrology Service Agency, 1996). Several previous studies showed that the yield and quality of African marigold is greatly influenced by the prevailing environment during their growth period (Naik *et al.*, 2005; Prakash *et al.*, 2016; Ahmad *et al.*, 2017; Khobragade *et al.*, 2019). Accordingly, the implementation of well-planned research and experimentation, which displays the optimum production conditions are prerequisite steps for effective production and sustainable buildup of the African marigold industry. Therefore, the present study was designed with the objective of evaluating the performance of three African marigold varieties for vegetative growth, flower characteristics, flower yield and xanthophyll content at six locations in Ethiopia.

MATERIALS AND METHODS

Testing Locations, Plant Materials and Cultural Managements

The experiment was conducted at six locations in Ethiopia using three African marigold cultivars (Hewoyde, AVT001 and AVT540) provided by India (AVT Natural Products Limited, Kerala, India). Detailed descriptions of the experimental locations are presented in Table 1. Seeds of the three cultivars were raised in the nursery seedbed for 45 days. Seedlings were transplanted to the main experimental fields arranged in randomized complete block design with three replications on ridges having 10 m length and width. A spacing of 30 cm between plants and 1 m between rows was maintained during planting. Pinching was done after 45 days of transplanting. Basal application of 45:90:75 kg ha^{-1} NPK was made at 8 days of transplanting and top dressing of 45 kg N ha^{-1} was applied after 45 days of transplanting. First irrigation was applied immediately after transplanting and once a week subsequently. All fields' cultural practices were performed whenever required.

Data Collection and Statistical Analysis

Data collection was made by taking 10 samples from the central rows of each plot. Measurements of flower parameters and harvesting were done when 80–85% of the flower was opened. Data on plant height (cm), number of branches $plant^{-1}$, number of flowers $plant^{-1}$, fresh flower weight (g), fresh flower yield $plant^{-1}$ (g), fresh flower yield ha^{-1} (t) and xanthophyll content (mg g^{-1}) were collected. Flower xanthophyll content (mg g^{-1}) was estimated according to the procedure given by the Association of Official Analytical Chemists [AOAC] as cited in (Beniwal *et al.*, 2017). The collected data were subjected to analysis of variance using SAS 9.4 v software (SAS, 2013), and presented as means ± standard error (SE). Differences between means were assessed using the least significance difference (LSD) test at $P < 0.05$.

RESULT AND DISCUSSION

Analysis of Variance

Mean squares from a combined analysis of variance for seven traits of three African marigold cultivars tested over six locations in Ethiopia are set out in Table 2. Location had a significant influence ($P < 0.01$) on the three African marigold varieties for all the studied characters. A significant effect of location on the performance of the varieties is expected because each testing locations varies in its soil type, rainfall and temperature (Table 1). A significant variation ($P < 0.01$; $P < 0.05$) among the tested African marigold varieties was also observed for plant height, number of branches/plant, individual flower weight, flower yield/ha, flower xanthophyll content, number of branches/plant and flower yield/plant. The interaction effects of location and varieties were significant ($P < 0.01$) for the number of branches/plant, number of flowers/plant, flower yield/plant and flower yield/ha. This indicates these traits were influenced by a change in the environment. In agreement with the present study, Fehr (1991) described that every factor that is a part of the environment of a plant has the potential

Table 1: Summary of site descriptions for the testing locations for performance evaluation of African marigold cultivars in Ethiopia

Testing locations	Latitude	Longitude	Soil pH	Soil type	Altitude (m.a.s.l)	Annual average temperature (°C)	
						Minimum	Maximum
Wondo Genet	07°1′N	38°35′E	6.4	sandy clay loam (Nitosol)	1876	12.02	26.72
Hawassa	07°05′N	39°29′E	7.2	Sandy loam (Andosol)	1652	12.94	27.34
Holleta	09°03′ N	38°30′ E	5.5	Red brown clay loam	2390	6.13	22.2
Qoqa	08°26′ N	39°1′ E	8.1	Clay loam	1604	13.68	28.30
Debere Zeit	08°44′N	38°58′E	6.9	Black heavy clay (Vertisol)	1891	12.22	25.72
Menagesha	09°03′N	38°34′E	5.4	Clay soil	2600	6	22

to cause differential performance. Similarly, fluctuations in features of the location such as rainfall, relative humidity, and temperature were reported as some of the environmental factors that cause performance variation in plants (Frankel *et al.*, 1994; International Rice Research Institute, 1996). Likewise, the influence of growing conditions on vegetative growth, flower characteristics and flower yield of African marigolds was also reported by Augustine *et al.* (2016).

Performances of African Marigold Cultivars in Vegetative Characters

Plant height

The overall average plant height of 59.5 cm was recorded and it ranges from 54.03 to 65.48 cm (Table 3). The highest value of plant height (74.58 cm) was obtained at Hawassa and the lowest (49.28 cm) was at Menagesha for cultivar AVT001 (Table 4). The range of plant height obtained in the present study is consistent with the report of Baskaran *et al*. (2017), Sharma *et al*. (2017) and Das *et al*. (2020) for African marigolds. Contrastingly, a taller pant height range (87.25–114.06 cm) was reported for African marigolds evaluated under different levels of nitrogen and potash application in Pakistan (Aslam *et al.*, 2016). The authors indicated that increase in plant height is directly proportional to the higher concentration of chemical fertilizers as compared to lower ones. The difference in plant height might be due to differences in environmental conditions, cultivar type and levels of chemical fertilizers. In addition to all these factors, plant spacing also has a significant influence on plant height. In narrower spacing, there is heavy competition between plants for light which results in the elongation of the main stem and crowded plants tend to grow vertically owing to the shadowing effect of the plants one on another (Kour *et al.*, 2012).

Number of branches/plant

The overall combined highest value of branch number/plant (89.09) was recorded for cultivar AVT001; while the lowest value was recorded for Hewoyde cultivar (64.66) (Table 3). A similar trend was also observed at individual locations and a higher branch number/plant (130.64) was obtained at Holleta for cultivar AVT001; while the lowest (45.84) was registered at Menagesha for Hewoyde cultivar (Table 4). Compared with the present study, lower values of branch number/plant were reported for African marigolds elsewhere (Naik *et al.*, 2005; Aslam *et al.*, 2016; Baskaran *et al.*, 2017). The wider plant spacing used in the current study compared with the mentioned earlier works might have favored the outgrowth of axillary buds which resulted in the formation of more branches. This could be the possible reason for the observed higher number of branches/plant in this study.

Performances of African marigold Varieties in Flowering Characters

Number of inflorescence/plant

The overall combined average value of the inflorescence number/plant was 64.95. The highest value was recorded for cultivar AVT001 which demonstrated a respective increase value of 13.17% and 53.39% compared with AVT540 and Hewoyde cultivars (Table 3). Across locations, the number of

Table 2: Mean square from the combined analysis of variance for three cultivars of African marigold tested over six locations

Source of Variation	DF	PH	NBPPL	NIPPL	WSI	IYPPL	IYPHA	FZC
Replication	2	2821.12	70858.52	33057.70	827.21	192415.95	150473971	0.36
Location (ℓ)	5	4863.20**	14371.78**	16179.15**	539.45**	1498978.22**	1602171918**	14.01**
Cultivar (c)	2	1187.04**	5452.35**	6734.80*	1233.44**	206573.35*	197753434**	1105.81**
ℓ*c	10	126.23**	3038.01^{ns}	4790.32*	73.13^{ns}	265741.68**	232446060*	4.29**
Error	34	119.39	5872.28	7541.79	388.46	100347.76	72592525	1124.46
R^2		98.69	94.10	88.95	87.31	95.56	96.78	99.98
CV(%)		13.15	16.90	22.92	17.20	10.90	19.08	10.62

**= Significant at $P<0.01$ level, *= Significant at $P<0.05$ level and ns=Non significant at $P<0.05$ level by the LSD test; PH=plant height (cm); NBPPL=Number of branches/plant; NIPPL=number of Inflorescence/plant; WSI=Weight of a single inflorescence (g); IYPPL=Inflorescence yield/plant (g); IYPHA=Inflorescence yield/ha (kg); FZC=Flower xanthophylls content (mg g^{-1})

Table 3: Over all mean performance of three African marigold cultivars across locations for vegetative, yield and biochemical characters

Cultivars	Parameters						
	PH	NBPPL	NFPPL	WSI	IYPPL	IYPHA	FZC
AVT001	65.48±2.16[a]	89.09±2.78[a]	76.89±2.65[a]	25.48±0.76[a]	560.77±42.23[a]	17996.4±1079.49[a]	21.20±0.12[b]
AVT540	58.98±2.27[b]	79.44±3.13[b]	67.94±3.14[a]	19.66±0.80[b]	519.73±52.12[b]	16800.4±1342.34[b]	27.60±0.13[a]
Hewoyde	54.03±2.12[c]	64.66±2.64[c]	50.03±2.48[b]	13.78±0.67[c]	413.95±31.85[c]	13473.3±880.51[c]	16.56±0.08[c]
Mean	59.50±1.25	77.73±1.65	64.95±1.60	19.64±0.43	498.14±25.23	16090.03±656.03	21.78±0.48
$LSD_{0.05}$	1.27	8.90	10.08	2.28	36.80	989.83	0.20
CV(%)	13.15	16.90	22.92	17.20	10.90	19.08	7.11

Means followed by the same letter with in the same column are statistically not different at *P<0.05* by the LSD test. PH=plant height (cm); NBPPL=Number of branches/plant; NIPPL=number of Inflorescence/plant; WSI=weight of a single Inflorescence (g); IYPPL=Inflorescence yield/plant (g); IYPHA=Inflorescence yield/ha (kg); FZC=Flower xanthophylls content (mg g^{-1})

Table 4: Performance of three African marigold cultivars at different testing locations of Ethiopia for vegetative, yield and biochemical traits

Location	Cultivars	PH	NBPPL	NIPPL	WSI	IYPPL	IYPHA	FZC
Wondo	AVT001	74.19±3.30[b]	91.52±3.32[bcd]	81.67±3.31[bcd]	28.90±0.96[a]	735.03±47.25[bc]	24381.92±132.25[b]	21.32±0.04[g]
Genet	AVT540	70.36±3.34[c]	102.85±3.43[ab]	96.30±3.41[ab]	21.94±0.93[cde]	852.35±64.27[a]	28126.03±244.54[a]	27.89±0.06[b]
	Hewoyde	60.75±3.01[fg]	68.52±3.11[efghi]	44.91±3.00[fgh]	20.04±0.91[cdef]	559.45±30.12[e]	18524.34±93.18[d]	16.44±0.04[m]
Hawassa	AVT001	74.58±2.90[a]	71.85±2.87[defgh]	55.57±2.82[efg]	28.7±0.97[a]	445.50±31.29[fg]	14730.94±70.67[ef]	20.81±0.04[i]
	AVT540	64.88±3.31[e]	55.52±2.99[hi]	44.22±3.32[fgh]	25.11±0.95[abc]	455.13±34.84[fg]	14885.25±75.52[e]	27.99±0.05[b]
	Hewoyde	63.68±3.11[ef]	47.18±3.01[i]	36.09±3.23[h]	17.14±0.64[efgh]	422.43±33.98[gh]	13957.08±71.54[efg]	17.15±0.03[k]
Koka	AVT001	72.19±3.32[bc]	83.99±3.41[bcde]	80.52±3.31[bcd]	27.74±0.95[ab]	666.85±45.25[cd]	22109.09±93.18[bc]	20.10±0.05[j]
	AVT540	68.74±3.56[cd]	91.64±3.66[bcd]	91.33±3.56[abc]	20.57±0.89[cdef]	729.54±47.55[bc]	24032.21±132.45[b]	26.50±0.06[d]
	Hewoyde	61.66±3.32[f]	78.96±3.33[cdefg]	79.56±3.43[bcde]	11.57±0.87[hi]	599.81±34.84[de]	19869.65±70.76[cd]	16.02±0.04[n]
Debre Zeit	AVT001	56.81±2.22[h]	83.01±2.42[cdef]	66.90±2.24[cdefg]	22.91±0.89[bcd]	376.52±14.70[ghi]	12431.57±35.48[fgh]	21.20±0.04[h]
	AVT540	50.56±2.56[i]	67.11±2.66[efghi]	51.77±2.57[fgh]	17.73±0.85[defg]	304.06±13.92[ij]	9849.57±35.40[ij]	26.88±0.06[c]
	Hewoyde	42.35±2.44[jk]	45.84±2.55[i]	28.29±2.34[h]	12.37±0.79[ghi]	195.67±12.81[k]	6398.27±28.52[k]	16.10±0.03[n]
Menagesha	AVT001	49.28±2.29[i]	73.56±2.93[defgh]	61.81±2.19[defg]	23.40±0.96[abc]	338.98±14.73[hi]	11180.18±34.58[hi]	22.11±0.04[e]
	AVT540	42.40±2.17[k]	62.15±2.25[fghi]	45.78±2.19[fgh]	17.26±0.88[efg]	252.16±13.92[jk]	8119.60±34.98[jk]	28.10±0.06[a]
	Hewoyde	40.68±2.56[k]	59.88±2.61[ghi]	42.87±2.58[gh]	12.87±0.81[ghi]	306.49±14.68[ij]	10092.44±35.51[hij]	17.11±0.02[k]
Holleta	AVT001	65.82±3.19[de]	130.64±3.22[a]	114.88±3.22[a]	21.23±0.98[cde]	801.69±47.25[ab]	23144.84±132.45[b]	21.60±0.05[f]
	AVT540	56.93±3.08[gh]	97.39±3.12[bc]	68.45±3.09[bcde]	15.37±0.94[fgh]	525.08±34.84[ef]	15789.55±70.67[e]	28.18±0.06[a]
	Hewoyde	55.07±3.36[h]	87.58±3.42[cde]	78.24±3.37[cdef]	8.67±0.91[i]	399.79±14.7[gh]	11997.88±35.49[ghi]	16.55±0.03[l]
Mean		59.50±1.25	77.73±1.65	64.95±1.60	19.64±0.43	498.14±25.23	16090.03±656.03	21.78±0.48
$LSD_{0.05}$		1.79	12.59	14.26	3.23	52.04	1399.8	0.08
CV(%)		13.15	16.90	22.92	17.20	10.90	19.08	3.50

Means followed by the same letter with in the same column are statistically non-significant at $P<0.05$ according to least significant difference (LSD) test. PH=plant height (cm); NBPPL=Number of branches/plant; NIPPL=number of Inflorescence/plant; WSI=weight of a single Inflorescence (g); IYPPL=Inflorescence yield/plant (g); IYPHA=Inflorescence yield/ha (kg)

inflorescence/plant ranged from 28.29 to 114.88. The highest number of inflorescence/plant was obtained at Holleta for cultivar AVT001 and the lowest was at Debre Zeit for cultivar Hewoyde (Table 4). The overall average value obtained in the present study is higher than the values reported in other countries for African marigolds (Karuppaiah & Kumar 2010; Kavitha & Anburani, 2010; Muthukrishnan *et al.*, 2013; Badge *et al.*, 2014; Idan *et al.*, 2014; Augustine *et al.*, 2016; Baskaran *et al.*, 2017; Das *et al.*, 2020). The higher number of inflorescence/plant obtained in the present study may be due to the development of more number of branches/plants. This can be confirmed by the observed strong and positive association of branches/plant (r=0.94**) with the number of inflorescence/plant in the current study (Table 5). Similar findings have also been reported by different researchers for the same crop (Bharathi *et al.*, 2014; Lohar *et al.*, 2018; Lalit *et al.*, 2020).

Inflorescence weight

The overall average fresh weight of single inflorescence was 19.64 g and ranged from 13.78 g (Hewoyde) to 25.48 g (AVT001) (Table 3). Compared across locations, the highest value was recorded for cultivar AVT001 at Holleta and for AVT540 at Wondo Genet; while the lowest value was obtained at Debre Zeit and Hawassa for cultivar Hewoyde (Table 4). The consistent result was also reported by Pushkar and Singh (2015) for African marigolds in other countries. On the other hand, lower values of single inflorescence weight (3.74–9.2 g) were reported in various works (Idan *et al.*, 2014; Sharma *et al.*, 2017; Singh *et al.*, 2017; Lohar *et al.*, 2018; Thirumalmurugan *et al.*, 2020). The variation in individual inflorescence weight in African marigold varieties may be due to genetic and environmental factors. The influence of cultivar, growing environment and

Table 5: Association among vegetative, yield and biochemical characters of three African marigold cultivars

	PH	NBPPL	NIPPL	WSI	IYPPL	IYPHA	FZC
PH		0.325*	0.408**	0.663**	0.700**	0.695**	0.099[ns]
NBPPL			0.938**	0.415**	0.593**	0.517**	0.131[ns]
NFPPL				0.429**	0.741**	0.670**	0.179[ns]
WSF					0.449**	0.446**	0.269*
FYPPL						0.974**	0.171[ns]
FYPHA							0.165[ns]
FZC							

**= a highly significant association at $P<0.01$, *= significant association $P<0.05$ and ns=non-significant association at $P>0.05$. PH=plant height (cm); NBPPL=Number of branches/plant; NIPPL=number of Inflorescence/plant; WSI=weight of a single Inflorescence (g); IYPPL=Inflorescence yield/plant (g); IYPHA=Inflorescence yield/ha (kg); FXC=flower xanthophylls content (mg g^{-1})

interaction between genotype and environment on the weight of individual inflorescence of African marigold was also reported in another earlier finding (Naik *et al.*, 2005). The influence of environmental factors on the single flower weight of African marigolds was also stated by Thirumalmurugan *et al.* (2020).

Performances of African Marigold Varieties in Yield and Biochemical Characters

Fresh inflorescence yield/plant

The overall combined fresh inflorescence yield/plant was maximum for cultivar AVT001 (560.77 g) and the least was recorded for the Hewoyde cultivar (413.95 g) (Table 3). On the basis of location performances, the highest value of inflorescence yield/plant (852.35 g) was recorded at Wondo Genet for cultivar

AVT540 and the lowest (195.67 g) was for Hewoyde cultivar at Debre Zeit (Table 4). The maximum values obtained for inflorescence yield/plant in the present study are higher than previous reports (Karuppaiah & Kumar, 2010; Muthukrishnan *et al.*, 2013; Badge *et al.*, 2014; Idan *et al.*, 2014; Augustine *et al.*, 2016; Baskaran *et al.*, 2017; Lohar *et al.*, 2018; Das *et al.*, 2020). The higher fresh inflorescence yield/plant may be due to the development of better vegetative and flower characters. Inflorescence yield/plant has a highly positive and significant association with plant height (r=0.70**), number of branches/plant (r=0.59**), number of inflorescence/plant (0.74**) and individual inflorescence weight (0.45**) (Table 5). Similarly, a significant and positive association of inflorescence yield/plant with the number of branches/plant, inflorescence weight, and number of inflorescence/plant was reported for African marigolds (Bharathi *et al.*, 2014). The highest values were obtained for inflorescence yield/plant in the present study, indicating the wider adaptability of African marigolds and the suitability of the prevailing agro ecologies of Ethiopia for the production of its flower.

Fresh inflorescence yield/ha

The overall combined fresh inflorescence yield/ha ranged from 18 t for cultivar AVT001 to 13.47 t for cultivar Hewoyde (Table 3). At individual locations, the highest fresh flower yield/ha (28.13 t) was obtained from cultivar AVT001 at Wondo Genet; while the lowest (6.4 t) was obtained from cultivar Hewoyde at Debre Zeit (Table 4).

Generally, the highest values obtained in the present study are greater than the previous reports on African marigolds (Badge *et al.*, 2014; Deepa & Patil, 2016; Gobade *et al.*, 2017; Renu *et al.*, 2017; Sharma *et al.*, 2017; Das *et al.*, 2020). The higher fresh flower yield/ha obtained at Wondo Genet in the cultivar AVT001 might be due to the development of yield contributing characters. This is supported by the significant and positive association of fresh inflorescence yield/ha with plant height (r=0.70**), number of branches/plant (r=0.52**), number of inflorescence/plant (r=0.67**), inflorescence weight (r=0.45**) and inflorescence yield/plant (r=0.97**) (Table 5). Likewise, a significant and positive association of inflorescence yield/ha with branch number/plant, flower number/plant and fresh flower weight/plant was also reported for African marigolds (Sahu, 2016).

Xanthophyll content

The overall combined mean flower xanthophyll content of the studied cultivar was 21.8 mg g^{-1}. It ranges from 27.6 mg g^{-1} (AVT540) to 16.6 mg g^{-1} (Hewoyde) (Table 3). Based on locations, the highest mean xanthophyll content was obtained at Holleta (28.18 mg g^{-1}) and Menagesha (28.1 mg $g^{-1)}$ for cultivar AVT540 (Table 4). Comparable xanthophyll contents of 20.19 mg g^{-1} (Lalit *et al.*, 2020), 20.20 mg g^{-1} (Karuppaiah & Kumar, 2010), and 22.5 mg g^{-1} (Gobade *et al.*, 2017) have also been reported for African marigold. On the other hand, the value obtained here is generally higher than the values reported by Ahmad *et al.* (2011) and Renu *et al.* (2017) for African marigold varieties in other countries.

Concerning the association of xanthophyll content with inflorescence weight, a positive and significant correlation was observed (r=0.27*) (Table 5). In agreement with the present study, a highly significant and positive association of individual flower weight with xanthophyll content was reported by Karuppaiah and Kumar (2010) and Bharathi *et al.* (2014) for African marigolds. This variation in xanthophyll content may be due to the difference in the genetic makeup of the genotypes, the prevailing growing environment or the interaction effect between the two (Naik *et al.*, 2005). Difference in isolation method and cultural practices could also be the cause for the variation (Pratheesh *et al.*, 2009).

CONCLUSION AND RECOMMENDATION

The values obtained in the present study under wider growing conditions of Ethiopia are within the ranges and/or higher than the values reported for morpho-agronomic and chemical characters in other African marigold growing countries. The AVT001 and AVT540 cultivars were found to be adapted very well in all testing locations for all vegetative growth, flower and chemical characteristics. Hence, the cultivars AVT001 and AVT540 can be recommended for the production of flowers for ornamental, herbal and xanthophyll content in the prevailing growing environments of Ethiopia.

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