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Genetic gain in grain yield and oil content of Noug (*Guizotia abyssinica*) in Ethiopia

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ABSTRACT

The primary and extended objective of plant breeding is to advance productivity to match the lengthening food requirements of people. Estimation of genetic advance from a breeding program and periodic evaluation of improvement in the genetic gain of a crop through released varieties is therefore needed to perceive changes and success generated by breeding activities. Periodic valuation of genetic progress of crop varieties is required to perceive the effectiveness of past breeding activities in genetic yield potential and prompt future selection criteria to aid further improvement. A total of 5 varieties have been released in Ethiopia, from 1988 to 2010. However, the level of genetic progress was not quantified. This study aimed to assess the genetic gain in seed yield potential and oil content of Noug (Guizotia abyssinica) and estimate changes made to yield related traits by genetic improvement of the crop. The experiment was conducted using 5 noug improved varieties and one local variety arranged in RCBD with four replications in 2016/17 main cropping season under rainfed condition. Results indicated that seed yield increased significantly during these 22 years. The estimated annual yield gain was 10.36 kg ha^{-1} year^{-1}(1.58% per year), reflecting the important efforts of the past breeding programs. Number of head per plant, number of seed per head, Seed yield per plant, biomass yield, harvest and oil content were also increased significantly by 1.72%, 1.71%, 1.85%, 0.33%, 1.03% and 0.34% per year, respectively. The endeavor should be encouraged and extended to accomplish more advances in these and other relevant traits. Noug breeding has not ascertained plateau in Ethiopia. Thus, development of higher yielding varieties of noug should persist to lengthen Noug grain yields if past tendency intends the prospective. To see the impact of the accomplishment in the genetic advance of noug research, it is compulsory to covenant huge scale popularization of the released varieties.

Key Words*: Noug (Guizotia abyssinica), genetic gain, yield potential, oil content and grain yield.*

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I. Introduction

Noug (niger seed) (*Guizotia abyssinica*) is a species in the composite that is used traditionally as an oilseed crop in Ethiopia, Eritrea and less extensively in India and several other countries in Africa and

South Asia (Getinet and Sharma, 1996). It is a dicotyledons plant, medium to well branched, up to 2 m high. Noug is native to Ethiopia where it cultivated on rotational basis with grains and legumes. Guizotia is a diploid species with 2x=2n=30 chromosomes (Hiremath and Murthy, 1992; Dagne 1994a). Noug (*Guizotia abyssinica*) is a semi domesticated oilseed crop, which is primarily cultivated in Ethiopia. Unlike its closest crop pertinent, sunflower, noug has fine seeds, small flowering heads, many branches, many flowering heads, and indeterminate flowering, and it shatters in the field (Dempewolf et al., 2015). Germination is epigeal and plants have hypocotyls and cotyledons that are pale green to brownish (Seegeler, 1983 in Getinet and Sharma, 1996). The crop is self-incompatible and heavily branched, and flowering heads and seeds are less than one-tenth the size of sunflower, its nearest oilseed crop relative (Funk et al., 2009).

The crop is familiar with small-scale farmers in Ethiopia as it grows well in unfavorable conditions such as water-logged soils and produces good yields under low-input circumstances. It is well integrated into the traditional planting cycle and produces edible oil in high demand on the domestic market (Getinet and Sharma 1996). Noug has been classified as a 'neglected and underutilized species' (Getinet and Sharma, 1996) and has embraced limited consideration from the scientific community. The seed contains approximately 40% oil with fatty acid composition of 75-80% linoleic acid, 7-8% palmitic and stearic acids, and 5-8% oleic acid (Getinet and Teklewold, 1995). The phenotypic diversity in noug is most evident for traits associated with flowering, maturity, head size, and other morphological characters. Noug is known for its high quality oil, although productivity per unit area is still really depressed. In Ethiopia, five improved varieties were released through the national oilseed improvement framework (IBC, 2007). Getinet and Tekelewold (1995) reported significant variability in oil content of noug that could be used for selection of high-oil-content of noug cultivar. They also reported a wide genetic variation in *Guizotia abyssinica* for agronomic traits: days to flowering, days to maturity and plant height, which could be utilized for breeding noug varieties for certain climatic and soil conditions.

In Ethiopia, research and development strategy for oilseeds is already in position regarding the oilseed and yield advance, which categorizes oilseeds according to agroecology, socioeconomics, extension and marketing systems (Alemu and Teklewold, 2011) although the achievements from the strategy may be in question. Extensive basic research and breeding work including modern biotechnological approaches, are needed to realize genetic improvement in this crop (Dagne, 2001b; Adefris and Girma, 2002). Developing self-compatible lines could be one of the target approaches for genetic improvement of noug (Sileshi et al., 1999). Noug seed populations in Ethiopia and India are highly heterogeneous, indicating the potential to improve yield through breeding. Both Ethiopia and India are valuable sources of germplasm for varietal development. Breeding objectives for noug seed are to increase seed yield and oil content and diminish shattering (Yadava et al., 2009).

The prime and long-term objective of plant breeding is to raise productivity in response to the growing food needs of population. Thus, estimation of genetic progress of a breeding program and the periodic assessment of the genetic gain of a crop is necessary to understand changes produced by breeding activities. It is also pertinent to evaluate the effectiveness of previous works to improve genetic yield potential and propose future selection guidance to facilitate subsequent improvement. Documenting the contribution of plant breeding to a given crop yield betterment and assessing the past gains help distinguish areas with potential for planning a future breeding program (Waddington et al., 1986). As clearly indicated by Evans (1999), if future breeding progress aims to increase the seed yield with sufficient and quality traits, it is beneficial to study advances made on yield attributes with year of release by past genetic improvements.

Hence, genetic advance achieved in seed yield and related alters in yield attributes produced by genetic improvement and advantage possess by comparing old and modern varieties, thereof, have been documented in distinct crops [wheat (Amsalu et al., 1995; Ustun et al., 2001); tef (Yifru and Hailu, 2005); common bean (Kebere et al., 2006); faba bean (Tamene, 2008; Lange and Federizzi, 2009); barley (Wondimu, 2010); soybean (Jin et al., 2010; Hailu et al., 2010; Demisew, 2010); linseed (Ersullo et al., 2016); chickpea (Belete et al., 2017); field pea (Teshome, 2011); sesame (Tafese, 2011); lentil (Daniel, 2011) and groundnut (Fikre et al., 2012)]. Regardless of the significance of genetic gain for crops genetic improvement, such information is not available on Noug in this area. Therefore, this

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work was designed to assess the genetic gain in seed yield potential and oil content of Noug (*Guizotia abyssinica*) and to estimate changes made to yield related traits by genetic improvement of the crop.

II. Materials and Methods

Description of the study area

The trial was done at four locations of Wollega University Shambu campus farming district (Shambu campus demonstration site, Harato demonstration site, Gitilo demonstration site and Horro Guduru animal production and research center) during rainy season of 2016/17 G.C. The farming sites are located in western Oromia region state of the western part of Ethiopia. The two farming stations Harato and Gitilo are laid at the Southern and western parts of the Shambu town in Jimma Geneti and Horo district, respectively. Shambu campus demonstration site is laid in Shambu Campus. Guduru animal production and research center are laid in the eastern part of the Shambu town in Guduru district. The altitude of the four areas ranges between 1500-2200m.a.s.l. (medium to high altitude). The four study areas are characterized by mono-modal rainfall distribution for six months from April to October and the research centers receive the average annual rainfall ranging from 1200-2000mm. The annual average temperature of the four areas ranges from 18-22˚c. The cropping patterns of the study areas are dominantly cereals crop, the soil is clay loamy textural class according to a report of (HGZAB, 2010).

Experimental materials

Five released noug variety and one local variety was evaluated over four sites during (2016/17) main cropping season in four potential productions (Shambu, Harato, Gitilo and Guduru) areas of Horo Guduru Wollega, Ethiopia. The description of variety was given in Table 01.

Table 01. Description of variety used in the study

S.N.	Variety name/Acc. No	Year of release	Maintaining center
1	Ginchi	2010	HARC (Holleta Agricultural Research Center)
2	Shambu-1(PGRC/E 228423)	2002	HARC
3	Kuyu	1994	HARC
4	Fogera	1988	HARC
5	Esete-1	1988	HARC
6	Local variety	Pre-1988	Farmer

Experimental design and treatments

Randomized complete block design (RCBD) with four replications was used in all test sites. The plots were made of 4 rows with 4 m long. The spacing between the rows and between the individual plants in a row was 40cm and 20cm, respectively. The gross plot size for noug seed was (4m x 0.40 m x 4 rows) =6.4 m^2 and the central 2 rows (4 m x 0.40m x 2 rows) = 3.2 m^2 was harvested. A 1-meter distance was maintained between replications at all sites. The trial was planted in June 2016 at each testing site. Urea and DAP fertilizers were applied at the time of sowing to initiate vegetative growth of plant and other crop management was carried out equally.

Data collected

Ten sample plants were selected from each plot for which all the data was recorded except days to flowering and days to maturity.

- **Days for flowering (50%flowering)**: It was recorded when 50% of the plants in a plot reach the respective phonological stages.
- **Days for maturity (90% petals fall):** It was recorded when 90% of the plants in a plot reach the respective phenological stages
- **Plant height (centimeters)**: -Measured in centimeter and ten plants sampled randomly from the central row at flowering stage. The total measured plant height was summed and divided by the numbers of plant to get height per plant.
- **Number of primary branches per plant**: The number of branches was counted in ten randomly selected plants at physiological maturity per plot.
- **Biomass yield**: Recorded from all plants per plot and sun drying to a constant weight.

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- **Number of heads per plant (capitulum)**: Recorded from the count of ten randomly sampled plants per net plot at harvesting.
- **Number of seeds per head (capitulum)**: Recorded from the count of five randomly sampled heads from the ten sampled plants per net plot at harvesting.
- **Seed yield per plant**: Determined from the ten randomly sampled plants per net at harvesting and was adjusted to 10% moisture level.
- **Grain yield**: Determined from the net area and was adjusted to 10% moisture level.
- **Harvest Index (%):** Computed as the ratio of grain yield to above ground dry biomass per net plot and multiplied by 100%.

Oil content

Determination of moisture content

Moisture content was determined according to the Ethiopian Standard (QSAE, 2001). The seed moisture determination was done for all samples from all plots by drying at a temperature of 103⁰C in a temperature controlled oven at atmospheric pressure until the change in successive mass is constant. The drying sample was frequently taken out to desiccators with silica gel to cool before weighing.

Determination was done for the whole seed the result was expressed as percentage by mass

$$M = \frac{(m1 - m2)}{m1 - m0} * 100$$

Where,

M =moisture and volatile matter
m1 =the mass, in grams, of the petridish and the test portion before drying
m2 =the mass, in grams, of the petridish and the test portion after drying
mo =the mass, in grams, of the petridish

Determination of total ash content

Determination of total ash was done according to Ethiopian Standard (QSAE, 2001). According to this standard total ash refers to the residue obtained after incineration at 550+15ºC in an electrically heated muffle furnace until the change in mass was nil. The result of every analysis was expressed as percent by mass and data was taken in triplicate.

$$\text{Total ash} = \frac{(m2 - m0)}{(m1 - m0)} * 100$$

Where,

m2 =the mass, in grams, of the ash and the dish;
m1 =the mass, in grams, of the dish and the sample;
mo =the mass, in grams, of the dish

Determination of oil content

The oil content was determined according to Ethiopian standards (QSAE, 2005). 30g cleaned seed samples were prepared to represent each plot and carefully ground using coffee grinder with repeated shaking and grinding to make it as uniform size as possible and good size reduction without clumping or forming paste. Grinding was done by frequent interruption to minimize heating of the sample. The flour was passed through a 1 mm aperture sieve to ensure uniformity of particle size to determine the frequency of grinding by the grinder as a pre-run. The flour was then extracted with hexane (analytical grade) using sox let extractor and the hexane was recovered by distillation and using a chiller. The last trace of solvent was dried at 103°C for 60 minutes at atmospheric pressure. The extracted oil was weighed using an analytical balance of precision of 0.0001. Finally, the oil content was determined by oil/seed (m/m %). The mean of the triplicate was taken as an oil content of the samples. The oil content was calculated on dry basis.

$$\text{Oil Content (\%)} = \frac{m1}{m2 - (m2 * w)} * 100$$

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Where,

m1 =mass of dried extracted substance in gram
m2 =mass of test portion in gram
w =percent of moisture

Statistical analysis

Analysis of variance (ANOVA) was performed using PROC ANOVA of SAS software to assess differences among varieties as per the procedures suggested by Gomez and Gomez (2004). Homogeneity of error means square between the four sites was tested by the F-test on variance ratio. Combined analysis of variance was performed for those parameters when error mean squares was homogenous using PROC SAS software. Mean separation was done using Duncan's Multiple Range Test (DMRT).

Individual location ANOVA model

$$Yij = \mu + Gi + Bj + eij$$

Where:

Y_{ij} =observed value of genotype i in block j,
μ =grand mean of the experiment,
Gi =effect of genotype i,
Bj =effect of block j
e_{ij} =random error effect of genotype i in block j

Combined ANOVA model

$$Y_{ijk} = \mu + G_i + E_j + GE_{ij} + B_{k(j)} + e_{ijk}$$

Where,

Y_{ijk} =observed value of genotype i in block k of location j
μ =grand mean, G_i – effect of genotype i, E_j - environmental or location effect j
GE_{ij} =the interaction effect of genotype i with location (environment) j
$B_{k(j)}$ =effect of block k in location (environment) j
E ijk =random error (residual) effect of genotype i in block k of location

The functional form of linear relationship between a dependent variable Y and independent variable X is represented by the following equation.

$$Y = \beta 0 + \beta 1$$

Where

Y =the value of the dependent variable,
X =the independent variable,
β0 =the intercept of the line,
β1 =the regression coefficient or slope of the line, or the changes in y per unit change in x.

$$\text{Annual rate of gain (b)} = \frac{\text{CovXY}}{\text{VarX}}$$

Where,

Cov =Covariance,
Var = Variance,
X = the year of release of the variety,
Y = the mean value of each character for each variety.

The relative annual gain achieved over the years in seed yield, oil content and on different agro morphologic characters for noug was determined as a ratio of annual genetic gain to the corresponding mean value of oldest variety and expressed as percentage. The correlation coefficient was calculated as stated under:

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$$rxy = \frac{\text{Cov (X, Y)}}{\sqrt{\text{V(X)(V(Y)}}}$$

Where,

rxy = correlation coefficient between x and y,
Cov(x,y) = Covariance between x and y
V(x) = Variance of x,
V(y) = Variance of y

Or

$$\text{rxy} = \frac{\sum[(\text{x} - \bar{\text{x}})(\text{y} - \bar{\text{y}})]}{\sqrt{[\sum(\text{x} - \bar{\text{x}})^2 \sum(\bar{\text{x}} - \bar{\text{y}})^2}}$$

Where,

rxy = simple correlation coefficient between characters x
y;$\bar{x}$ =Mean of character x and
$\bar{y}$ =Mean of character y

III. Results and Discussion

Grain yield potential

The joint analysis of variance over location indicated that all varieties, location and varieties X location effects were significant (P≤0.01) for seed yield (Table 02). Grain yield, which is an important agronomic parameter, was significantly affected by interaction effect of genotypes and locations indicating that the test varieties performed differently at test locations. This might be due to the past breeding effort to develop varieties that perform relatively well over narrow range of environments for grain yield potential of noug and varieties were not tested for wide adaptation under many zones (locations). Mihret (2012) and Kebere et al. (2006) also observed highly significant difference between genotypes and genotype x location interaction, for most traits including grain yield in sorghum and haricot bean, respectively. On the contrary, Yifru and Hailu (2005)and Fano (2013) found the highly significant variation in grain yield of varieties and the non-significant variety x location interaction for grain yield of in tef. Fikre et al. (2012), Ersullo et al. (2016) and Belete et al. (2017) also reported variation in grain yield of varieties and location but the non-significant variety x location interaction for grain yield in groundnut, linseed and chickpea, respectively.

Table 02. Mean squares (MS) for the combined analyses of variance of the characters the 6 noug cultivars over the four test location

No	Character	Location(3)	Rep with loc.(15)	Variety(4)	Loc XVar(15)	Error	Mean	CV	R^2
1	DF	2928.19**	13.61ns	879.57**	390.89**	23.78	91.42	5.33	0.92
2	DM	3044.04**	3.56ns	690.24**	340.51**	20.82	150.85	3.02	0.92
3	PH	4471.03**	504.78**	3300.96**	36.86^{ns}	155.73	100.90	12.37	0.75
4	NPB	13.29**	7.85**	10.88**	0.618^{ns}	0.96	9.29	10.52	0.66
5	NHPP	3207.68**	1519.26**	1110.93**	37.98^{ns}	83.20	53.04	17.19	0.78
6	NSPH	216.10**	12.66^{ns}	200.90**	13.78**	5.78	20.78	11.57	0.83
7	SYPP	4.60**	0.13ns	3.63**	0.26ns	0.16	2.72	14.58	0.78
8	BY	6019737.41**	425830.39**	531070.80**	102564.14ns	139062.17	2517.56	14.81	0.71
9	GY	489023.82**	34647.33**	261260.51**	14608.60**	5577.22	711.62	10.49	0.89
10	HI	156.86**	6.88ns	191.94**	16.47ns	12.02	28.45	12.18	0.68
11	MC	5.22**	0.75ns	0.62*	1.55**	0.31	5.73	9.66	0.68
12	AC	5.42**	0.36ns	1.32**	0.51**	0.18	4.06	10.59	0.71
13	OC	178.09**	19.016	311.34**	15.49ns	9.15	40.16	7.53	0.79

*&** = Significant at P ≤ 0.05 and P ≤ 0. 01, respectively, ns=non-significant DF=days to flowering, DM =days to maturity, PH =plant Height, NPB= number of primary branches, NHPP= number of head per plant, NSPH= number of seed per head, SYPP= seed yield per plant (gm/p), BY= biomass yield (Kg/ha), GY= grain yield (Kg/ha), HI= harvest index (%), MC= moisture content (%), AC= ash content (%), OC=oil content (%)

The average grain yield of noug varieties was 711.62 kg ha^{-1}, which ranged from 524.0 kg ha^{-1} for the local variety to 884.32 kg ha^{-1} for the variety released in 2010 (Ginchi). The recently released variety Ginchi was the first best yielder among the 5 varieties, and it was highly significantly (P ≤ 0.01)

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different from the four varieties (Shambu-1, Kuyu, Fogera and Estete in Table 03 and Table 05). As shown in Table 04, the superiority of the higher yielder variety, Ginchi express 884.32 kg ha^{-1} or 68.75 % increment over local variety and 34.65% over the average of the first two older varieties (Fogera and Estete). Consistent with these findings, genetic advances have been noted in various crops. Miller and Yilma (1984) reported consistently greater grain yield of new varieties as compared with old hybrid across location. Tef grain yield of the newly released cultivar showed superior grain yield than older varieties (Yifru and Hailu, 2005). Similarly, in tef, the newly released variety was the first best yielder among tested varieties (Fano, 2013). Shearman et al. (2005) noted that the seed yield of recently registered wheat varieties was performed better than older varieties. Likewise, Wondimu (2010), who worked in malt barley, reported an increment in seed yield of modern varieties over the farmer's variety and the oldest improved variety. Similarly, Amsalu et al. (1995) reported highest (6610 kg ha^{-1}) grain yield of recent variety of bread wheat at Holetta and 4820 kg ha^{-1} at Kulumsa showing an increase in yield potential of 89 and 71%, respectively.

In addition, Tamene (2008) indicated an increment in grain yield of modern varieties as high as 907 kg ha^{-1} (37%) over the older varieties from faba bean and Demissew (2010) reported highest grain yield of 81.25 (7.78%), 108.00 (10.34%), 177.09 (16.95%) and 744.51 (71.27%) kg ha^{-1}for soybean varieties released in 1981, 2003, 2005 and 2007 than that of the first released varieties respectively in Ethiopia. Kebere et al. (2006) reported an increment in grain yield over the local variety in common bean. As a result, grain yields rose considerably with dissemination of advanced varieties. According to Fikre et al. (2012), grain yield of newly registered variety was greater than all varieties represented in the trial and exceeded the old variety in groundnut. Ersullo et al. (2016) also reported very recent variety of linseed ranked first in grain yield. This provides an idea for future possibilities to utilize the genetic potential of the crop to improve production.

Table 03. Mean value of characters obtained from combined analysis of yield and yield components of Noug varieties

Variety	DF	DM	PH	NPB	NHPP	NSPH	SYPP (gm)	BY	GY (kg/ha)	HI (%)	MC (%)	AC (%)	OC (%)
Ginchi	82.81c	142.81c	95.58b	9.56ab	65.69a	25.44a	3.42a	2649.5a	884.32a	33.58a	5.87a	3.72d	45.90a
Shambu-1	82.88c	143.00c	96.59b	9.54ab	59.71ab	23.96a	3.07b	2687.1a	810.66b	30.50b	5.63ab	4.06bc	43.57b
Kuyu	94.81	154.44b	98.16b	10.14a	53.64bc	21.72b	2.78c	2574.2ab	737.16c	28.89bc	5.66ab	3.93bcd	40.89c
Fogera	92.56b	152.31b	91.29b	9.37b	48.11cd	18.88c	2.56cd	2601.6ab	665.19d	27.96cd	5.90a	3.87cd	39.57cd
Estete	93.50b	153.50b	93.94b	9.4b	47.11d	18.52c	2.30de	2373.4bc	648.31d	26.26d	5.41b	4.22b	37.6d
Local	101.93a	159.06a	129.83a	7.70c	43.95d	16.15d	2.16e	2219.6c	524.03e	23.54e	5.90a	4.53a	33.43e
Mean	91.42	150.85	100.90	9.29	53.04	20.78	2.72	2517.56	711.62	28.45	5.73	4.06	40.16
CV	5.33	3.02	12.37	10.52	17.19	11.57	14.58	14.81	10.49	12.18	9.66	10.59	7.53

Means with in a column followed by the same letter are not significantly different at P ≤ 0.05 according to Duncan's Multiple Range Test (DMRT), DF=days to flowering, DM =days to maturity, PH =plant Height, NPB= number of primary branches, NHPP= number of head per plant, NSPH= number of seed per head, SYPP= seed yield per plant (gm/p), BY= biomass yield (Kg/ha), GY= grain yield (Kg/ha), HI= harvest index (%), MC= moisture content (%), AC= ash content (%), OC=oil content (%)

Average grain yields of varieties released in 1990s, 2000s, and 2010s were higher than local and the first two older varieties released in 1980s (Table 04). Overall, grain yield increased from old varieties to new varieties over the last three decades of noug breeding in Ethiopia. This implicates that noug breeders tried a lot to improve noug grain yield potential. This is in agreement with the findings of Yifru and Hailu (2005) and fano (2013) in tef, Wondimu (2010) in malt barley, Riggs et al. (1981) in spring barley, Amsalu et al. (1995a) in bread wheat at Holetta and Kulumsa, Austin et al. (1980) in Winter wheat, Amsalu (1994) in Ethiopian rainfed wheat, Tamene (2008) in faba bean, Kebere et al. (2006) in common bean, Fikre et al. (2012) in groundnut, Ersullo et al. (2016) in linseed and Belete et al. (2017) in chickpea. All of these researchers observed a considerable increase in grain yield of modern varieties over the older ones.

The mean rate of increment in grain yield of noug varieties was 10.36kg ha^{-1}year^{-1} (Figure 01) and was highly significantly (P ≤ 0.01) different from zero (Table 06). This indicates that noug breeders have made substantial efforts over the last 22 years to improve the yields of noug in the country. Similar trends have been reported in tef (Yifru and Hailu, 2005), spring barley (Riggs et al., 1981), oat (Wych and Stuthman, 1983), winter wheat (Austin et al., 1980), and wheat (Amsalu, 1994). Grain yield potential of successively released haricot bean and faba bean varieties in Ethiopia increased at a rate

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of 65.54 and 18.10kg ha^{-1} year^{-1} (Kebere et al., 2006; Tamene, 2008), respectively. Likewise, Amsalu (1994) in 33 durum wheat, Wondimu (2010) in malt barley and Demissew (2010), in soybean found a considerable increment in grain yield across the year of release. Similarly, Fikre et al. (2012) in groundnut, Ersullo et al. (2016) in linseed and Belete et al. (2017) in chickpea.

The relative annual genetic yield gain in 5 varieties of noug released between 1988 and 2010 was 1.58% year^{-1} (Table 07). Consistent with the current study, an annual increase of 1.6% has been reported by Miller and Yilma (1984) (1.6%), Unger and Baumhardt (1999) (1.2%) and Moyer et al. (2004) (0.7 %) in sorghum, Cox et al. (1988) (0.7%) in winter wheat, Yifru and Hailu (2005) (0.79%) and Fano et al. (2013) (0.56%) in tef and Miri (2009) (0.86%) in wheat, Karmakar and Bhatnagar (1996) (1.2%) in soybean Likewise, Hailu et al. (2009) in soybean in Nigeria and Ethiopia, Wondimu (2010) in malt barley and Demissew (2010) in soybean reported relative rates of gain of 2.2%, 1.34% and 1.27%, respectively. Graybosch and Peterson (2010) found the mean annual relative gain of 0.79 and 1.1% per year, respectively. Similarly, Kebere et al., (2006) (3.24%) in haricot bean, Ersullo et al. (2016) (4.15%) in linseed, Fikre et al. (2012) (1.89%) in groundnut, Belete et al. (2017) (0.55%) in chickpea, Teshome et al. (2011) (0.89%) in field pea and Tamene et al. (2008) in faba bean reported the relative annual genetic yield gain achieved through crop breeding in Ethiopia.

The regression analysis of variety yields with the number of years of variety release was performed for the varieties to observe the varietal improvement mover their older families (Figure 01). Accordingly, the annual genetic gain for grain yield accounts for 10.36 kg ha^{-1} year^{-1}representing the relative genetic gain of 1.58% per year indicating better achievements for these varieties (table 07). Fikre et al. (2012) reported a linear regression between yield and year of release was highly significant ($P \leq 0.01$) across 33 years of groundnut breeding, 32.9% improvement of yield or 1.89% increase per year.

Generally, the findings of the current study showed that the noug improvement program that employed germplasm collection, selection, and hybridization was the major breeding method that contributed to the successful improvement in grain yield. There was no suggestion of yield potential plateau in Noug varieties throughout the study (Figure 01), which shows that further improvement possibility to increase yield and this provides hint for breeders further to exploit the yield potential of the existing noug varieties.

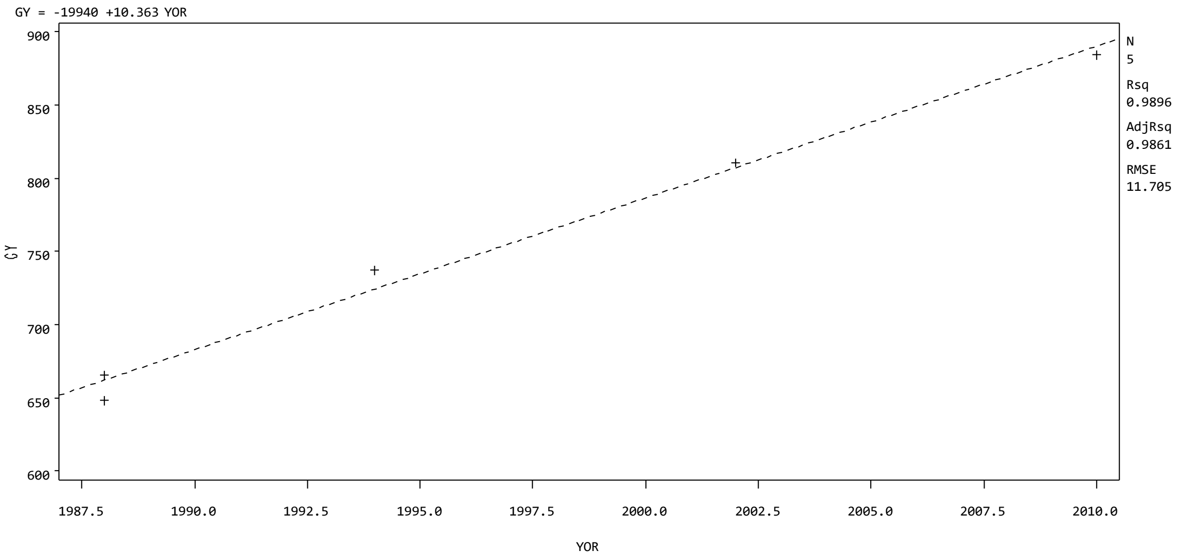

Figure 01. Association of mean grain yield (kgha^{-1}) of 5 Noug varieties and the year of release expressed as number of years since 1988.

Changes in yield related traits

Pooled analysis of variance for varieties, location and varieties by location interaction depicted significant difference for all yield related traits (Table 02). Number of head per plant, number of seed per head, seed yield per plant and biomass yield also revealed like seed yield during the 22 years, and

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newly released varieties had more number of head per plant, number of seed per head, seed yield per plant and biomass yield than old ones. Also, significant (P < 0.05) difference in different yield related characters was observed among the varieties released in the same period (Table 03). The most interesting finding in the present study is that newly released variety was the top yielding variety. Number of head per plant (65.69), number of seed per head (25.44), seed yield per plant (3.42) was Ginchi, but the top yielder for biomass yield (2687.1Kgha^{-1}) was Shambu-1. This demonstrates that both grain and Seed yields have been increasing during the research period (Table 04).

The annual gain for number of head per plant, number of seed per head, seed yield per plant over time associated to genetic gain in seed yield of noug is found to be significant and shows an increase of 0.82, 0.31, 0.05 year^{-1}, respectively (Table 07) with a relative change of 1.72%, 1.71% 1.85% over 22 years of noug breeding (Figure 03, Figure 05 and Figure 06). In line with the present finding, the study by Demisew (2010) indicated that mean pods per plant represented a highly significant increment in soybean genetic improvement programs over the years. Ribeiro et al. (2008) also indicated that number of pods per plant per year increased significantly but no change for the number of seeds per pod per year in some seasons of the test period. Similarly, Ersullo et al. (2016) reported significant differences for different traits that change per year during the first era. On the other hand, Kebere et al. (2006) reported an insignificant increment in pods per plant in haricot bean in Ethiopia.

Table 04. Mean grain yields (kgha^{-1}) and Oil content (%) of Noug varieties over all locations and increment over the local varieties

SL. No.	Variety	Year of Release	Mean grain yield (Kgha^{-1})	Mean oil content (%)	Increment over local variety			
					Deference	Increase (%)	Deference	Increase (%)
					Grain yield (Kgha^{-1})	Grain yield	Oil Content (%)	Oil Content
01	Local variety	Pre-1988	524.03	33.40	-------	-------	-------	------
02 03	Estete Fogera	1988	656.75	38.59	132.72	25.33	5.19	15.53
04	Kuyu	1994	737.16	40.89	213.13	40.67	7.49	22.43
05	Shambu-1	2002	810.66	43.57	286.63	54.70	10.17	30.45
06	Ginchi	2010	884.32	45.90	360.29	68.75	12.5	37.43

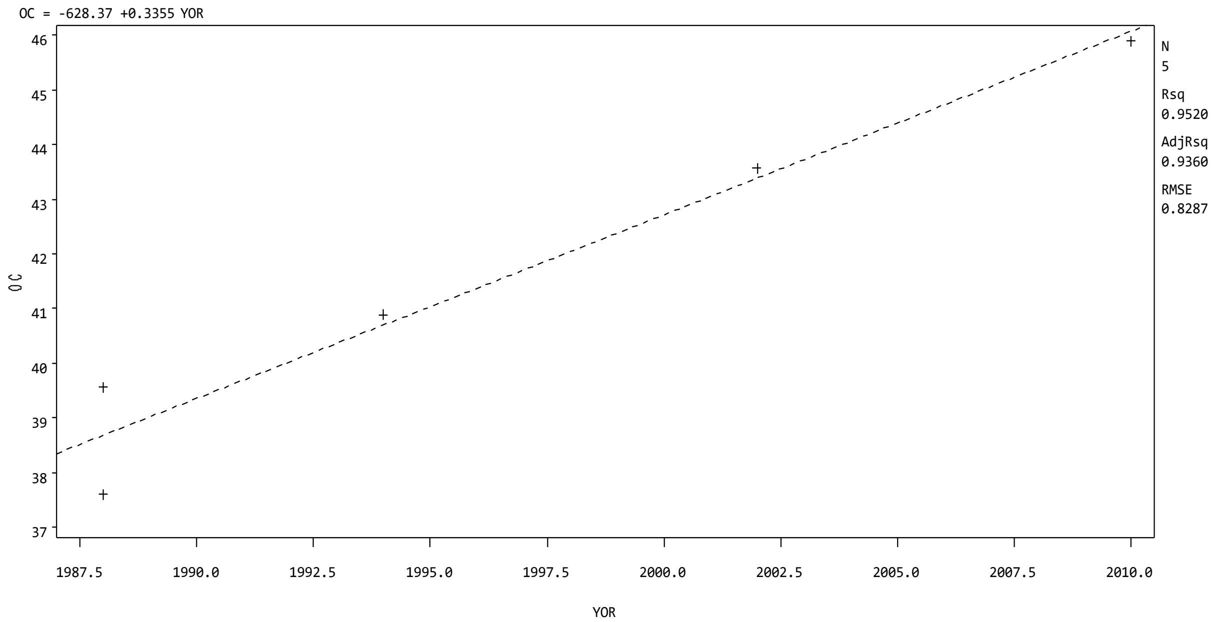

Figure 02. Association of mean oil content (%) of 5 Noug varieties and the year of release expressed as number of years since 1988

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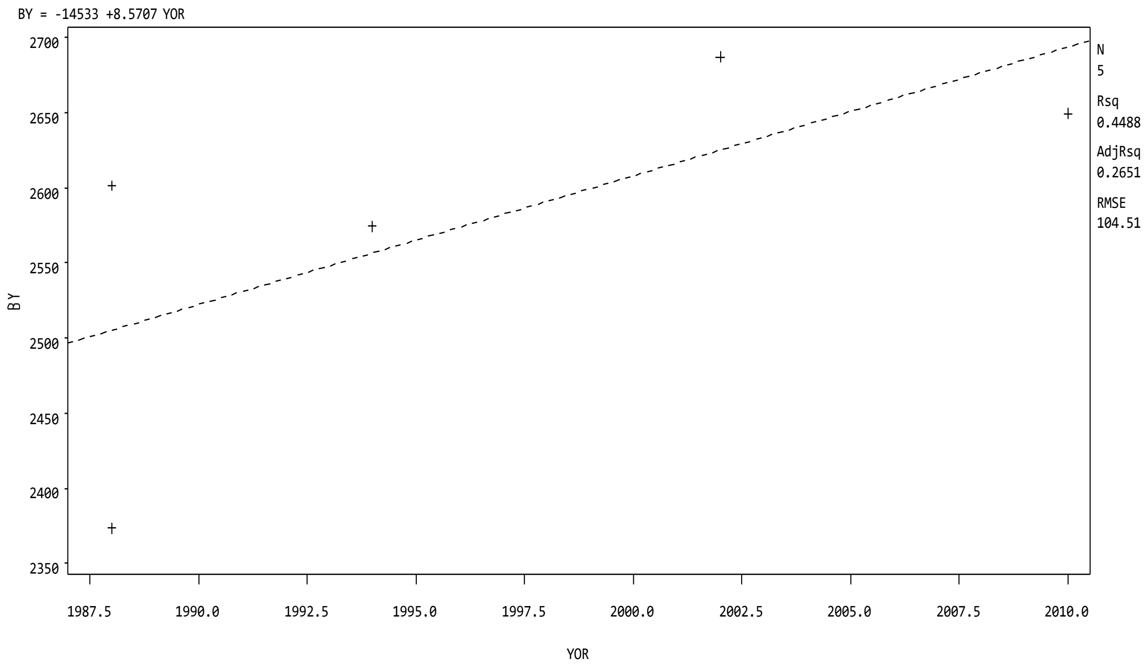

Figure 03. Association of mean biomass yield (kgha^{-1}) of 5 Noug varieties and the year of release expressed as number of years since 1988

Table 05. Average grains yield (kg ha^{-1}) and oil content (%) of 6 varieties grown at four locations

SL. No.	Variety	Guduru		Shambu		Gitilo		Harato		Varieties Mean	
		GY (kgha^{-1})	OC (%)	GY (kgha^{-1})	OC (%)	GY (kgha^{-1})	OC (%)	GY (kgha^{-1})	OC (%)	GY (kgha^{-1})	OC (%)
01	Local Variety	626.96e	31.16c	343.75d	34.62d	594.92d	31.43c	495.84c	36.62e	524.03e	33.43e
02	Estete	695.37de	38.76bc	533.00c	38.14c	865.40b	37.13b	488.59c	41.04d	648.31d	37.6d
03	Fogera	764.83cd	38.90b	563.29bc	39.04bc	757.85c	31.77c	574.81bc	41.63cd	665.19d	39.57cd
04	Kuyu	844.37c	42.03ab	641.38ab	41.90ab	861.33b	35.00b	601.57bc	44.63bc	737.16c	40.89c
05	Shambu-1	948.89b	39.53ab	633.01ab	43.20a	907.83b	43.64a	752.93a	47.95ab	810.66b	43.57b
06	Ginchi	1111.84a	46.76a	696.45a	44.865a	1039.55a	43.22a	689.45ab	48.75a	884.32a	45.90a
Mean		832.04	39.53	576.36	40.48	837.81	37.03	600.22	43.62	711.62	40.16
R^2		0.92	0.62	0.88	0.76	0.94	0.94	0.78	0.84	0.89	0.79
CV		7.54	12.83	9.35	5.67	5.31	4.38	12.95	5.18	10.49	7.53

Means with in a column followed by the same letter are not significantly different at P ≤ 0.05 according to Duncan's Multiple Range Test (DMRT), DF=days to flowering, DM =days to maturity, PH =plant Height, NPB= number of primary branches, NHPP= number of head per plant, NSPH= number of seed per head, SYPP= seed yield per plant (gm/p), BY= biomass yield (Kg/ha), GY= grain yield (Kg/ha), HI= harvest index (%), MC= moisture content (%), AC= ash content (%), OC=oil content (%)

Table 06. Mean values, coefficient of determination (R^2), regression coefficient (b) and intercept for different characters from linear regression of the mean value of each trait for each noug variety against the year of variety release since 1988 across location

Characters	Mean	R^2	b	Intercept
NHPP	54.85	0.99	0.82	-1589.62
NSPH	21.70	0.96	0.31	-604.22
SYPP	2.83	0.94	0.04	-86.26
BY	2577	0.45	8.57	-14533
GY	749.13	0.98	10.36	-19940
HI	29.44	0.94	0.28	-535.09
OC	41.50	0.95	0.34	-628.36

NHPP= number of head per plant, NSPH= number of seed per head, SYPP= seed yield per plant (gm/p), BY= biomass yield (Kg/ha), GY= grain yield (Kg/ha), HI= harvest index (%), OC=oil content (%)

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Table 07. Estimate annual relative genetic gain (RGG) of different characters over the 22 years of noug breeding in Ethiopia (based on average across four locations) and correlation coefficients of five noug varieties

Characters	Over all mean	Mean of the older variety	RGG (% Year^{-1})	Correlation coefficient (r)
GY	749.13	656.75	1.58	0.99**
BY	2577	2487.5	0.33	0.67ns
HI	29.44	27.11	1.03	0.97**
OC	41.5	38.59	0.88	0.98**
SYPP	2.83	2.43	1.85	0.97**
NSPH	21.70	18.7	1.71	0.98**
NHPP	54.85	47.61	1.72	0.99**

NHPP= number of head per plant, NSPH= number of seed per head, SYPP= seed yield per plant (gm/p), BY= biomass yield (Kg/ha), GY= grain yield (Kg/ha), HI= harvest index (%), OC=oil content (%)

The linear regression showed highly significant (P≤0.01) biomass yield of noug variety on the year of variety release during the study period (Table 04). As a result, biomass yield increased by 8.57kg ha^{-1} year^{-1} (Figure 03), indicating that noug genetic potential improvement program has significantly enhanced the biomass yielding ability of the modern varieties. Likewise, Boukerrou and Rasmussen (1990) reported that in spring barley breeding, total biomass and vegetative biomass (straw yield) increased at a rate of 22.5 and 6.8 kg ha^{-1} year^{-1}, respectively. Yifru and Hailu (2005) also reported that the biomass yield in tef was greater in newer varieties linearly associated with various age and grain yields. Moreover, improvement in yield potential of haricot bean and faba bean was associated with parallel increase in biomass yield in Ethiopia (Kebere et al., 2006; Tamene, 2008). Similarly, Fikre et al. (2012) indicated biomass yield was significantly and positively associated with pod yield (r = 0.83) and total number pod of per plant (r = 0.61) in groundnut. Teshome et al. (2011) and Ersulo et al. (2016) also showed in field pea and linseed increase in biomass yield in Ethiopia.

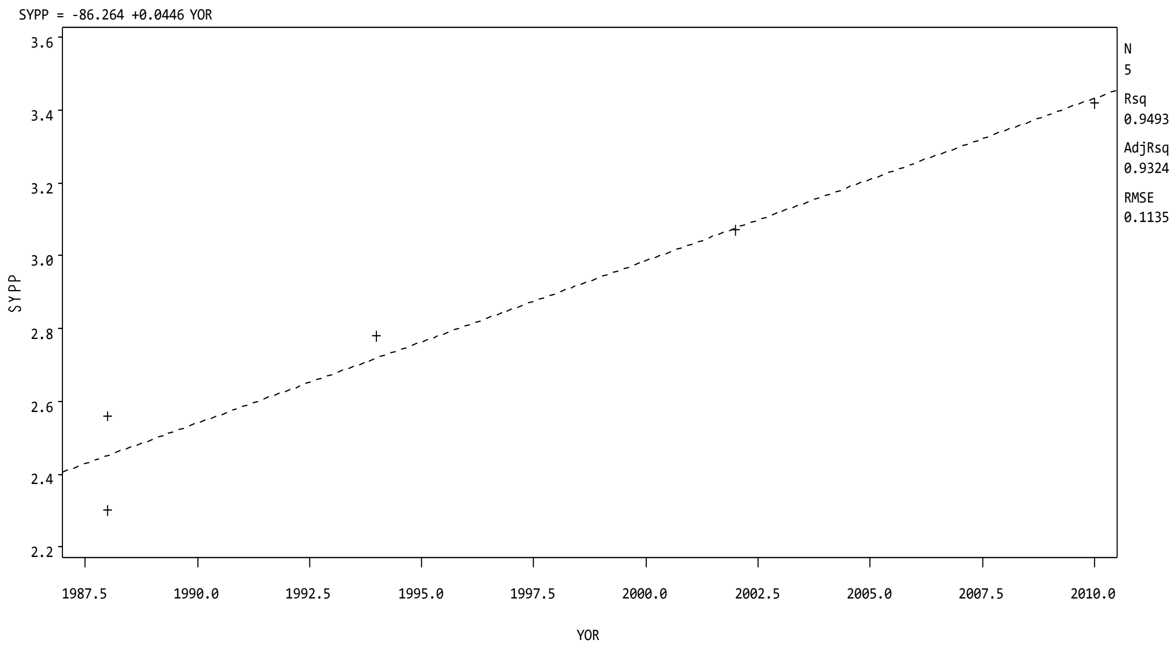

Figure 04. Relationship between mean seed yield per plant (gm/plant) of 5 Noug varieties and the year of release expressed as number of years since 1988

The combined analysis of variance for harvest index showed very significant (P≤0.01) location x variety interaction. Similarly, the combined analysis for harvest index indicated highly significant differences between the four locations and among varieties (Table 03). The present study results are in agreement with that of Solomon et al. (2009) in tef, showing that harvest index showed significantly (P≤0.05) affected by variety x location interaction. Mihret (2012) in sorghum, Yifru and Hailu (2005) in tef and Malik et al. (2010) in chickpea reported that harvest index was highly significant among genotypes. It was shown that varieties were markedly (P< 0.01) different from each other in harvest index. Advanced varieties established large harvest index relative to the local variety An increase which is greater than units of percent in harvest index was achieved when the oldest varieties compared with the newest once (Table 07).

Similarly, linear regression coefficient revealed that harvest index showed a positive and significantly different from zero (P< 0.01) with year of release of the varieties (Table 06). In agreement with these findings, Jin et al. (2010) showed a substantial increment of harvest index with a year of release in released soybean cultivars. Harvest index obtained ranged from 0.24 to 0.34 with a mean of 0.29 (Table 03). Likewise, Fikre et al. (2012) reported harvest index ranged from 0.243 to 0.327 with a mean of 0.270, but there was no significant increment in harvest index. The result is inconsistent with Kebere et al. (2006) in common beans and Hailu et al. (2009) in soybean, who reported unchanged harvest index for the period of genetic improvement.

The average rate of increase in harvest index was also 0.28 year^{-1} and the progress occurred at an annual rate of 1.03% increase for the last two decades (Table 07). This depicts that improved potential for noug genetic yield has been attributed to improved dry matter allocation ability in Ethiopia. Similarly, yield potential advancement in bread wheat and durum wheat made visible favorable alter in harvest index (0.42% to 0.54% year^{-1}) in Ethiopia (Amsalu, 1994). Nonetheless, Abeledo et al. (2003) in barley, Yifru and Hailu (2005) in tef, Kebere et al. (2006) in haricot and Tamene (2008) in faba bean found that harvest index was unsteadily modified with the year of release of the varieties in related crop species they studied. On the other hand, it was witnessed by other authors that grain yield improvement was parallel with an increase in harvest index and biomass yield. Martintello et al.(1987) reported that gain in biomass yield was not uniform for six-row varieties while that of two-row barley varieties increased by 64 kg ha^{-1} (0.46%) year^{-1}. It was evident that grain yield improvement in the modern two rowed genotypes depends on the biomass yield and harvest index while gain in grain yield for six rowed barley genotypes has been obtained by improving the harvest index only. Similarly, yield increment in spring barely related to raising of biomass yield, harvest index and reduction of plant height (Bulman et al., 1993).

Changes in oil content

The combined analysis of variance for oil content revealed very significant (P≤0.01) variation between the four locations and among variety but insignificant location x variety interaction (Table 03). Likewise, Ersullo et al. (2016) reported highly significant (P≤0.01) differences between the four locations, among variety and location x variety interaction. On the contrary, Fikre et al. (2012) reported, although there were variations among the varieties in oil concentration, insignificant change was observed during the past 33 years in groundnut. This may be because groundnut breeders may have focused more on selecting high-yielding varieties, rather than genetic improvement in this quality trait. Similarly, Jin et al. (2010) also found that the absence of significant improvement in oil content among the soybean varieties over the 56 years of improvement work.

The average oil content of noug varieties was 40.16%, ranging from 33.43 for the local variety to 45.90% for the variety released in 2010 (Ginchi) (Table 03 and Table 05). The recently released variety Ginchi was the first to produce highest yield among the 5 varieties, and it was very significant (P ≤ 0.01) different from the four varieties (Shambu-1, Kuyu, Fogera and Estete (Table 03). As shown in Table 03, the superior yield of the variety, Ginchi shows 45.90% or 37.43 % increment over local variety and 15.53% above the mean of the first two older varieties (Fogera and Estete) (Table 04). Similarly, Ersullo et al. (2016) reported the mean oil content within each decade relative to local cultivar; there were benefits of 10.66, 7.30, 9.46 and 10.90% in 1980s, 1990s, and 2000s and in pipeline varieties in linseed. The mean rate of lengthen in oil content of noug varieties was 0.34% year^{-1} (Figure 02) and was significantly (P ≤ 0.01) varied from zero (Table 05). This suggests that noug breeders have put significant efforts into improving the oil content of noug in the country over the last 22 years. Consistent patterns were reported in groundnut and linseed (Fikre et al., 2012; Ersullo et al., 2016)

The comparative rate of gains per year of release of varieties improved since 1988 for oil content (0.88% year^{-1}) was significant (Table 05 and Figure 02). The genetic gains in varieties produced over years of release for this trait since 1988 were significantly (P ≤0.001) different from zero with an estimated annual rate of increase about 0.34% % since 1988 (Table 05 and Figure 02). In

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disagreement with the result, the relative rate of gains per year of release of linseed varieties produced since 1984 for oil content (0.05% year^{-1}) was insignificant (Ersullo et al., 2016). Oil content of noug varieties showed a significant (P ≤ 0.05) and positive association with grain yield and the regression coefficient (b = 0.34) revealed that there was significant trend for this trait from the older to the newest variety (Table 06 and Table 07). Likewise, Fikre et al. (2012) found similar results in oil content of groundnut varieties. In contrary to the findings of this study, Faisal et al. (2006) found a negative association of oil content with grain yield of soybean. According to the author, genetic gain for grain yield was positive (59.8 kg ha^{-1}year^{-1}) due to the higher number of seeds per plant, higher grain yield per plant, higher pod yield and greater plant biomass yield. A similar result was also obtained by Ribeiro et al. (2008) in common bean. Thus, in light of this study, it could be pointed out genetic yield potential improvement of noug varieties over the last 22 years has been mostly associated with an accompanying increase of oil content, seed yield per plant, seed number per plant and biomass yield.

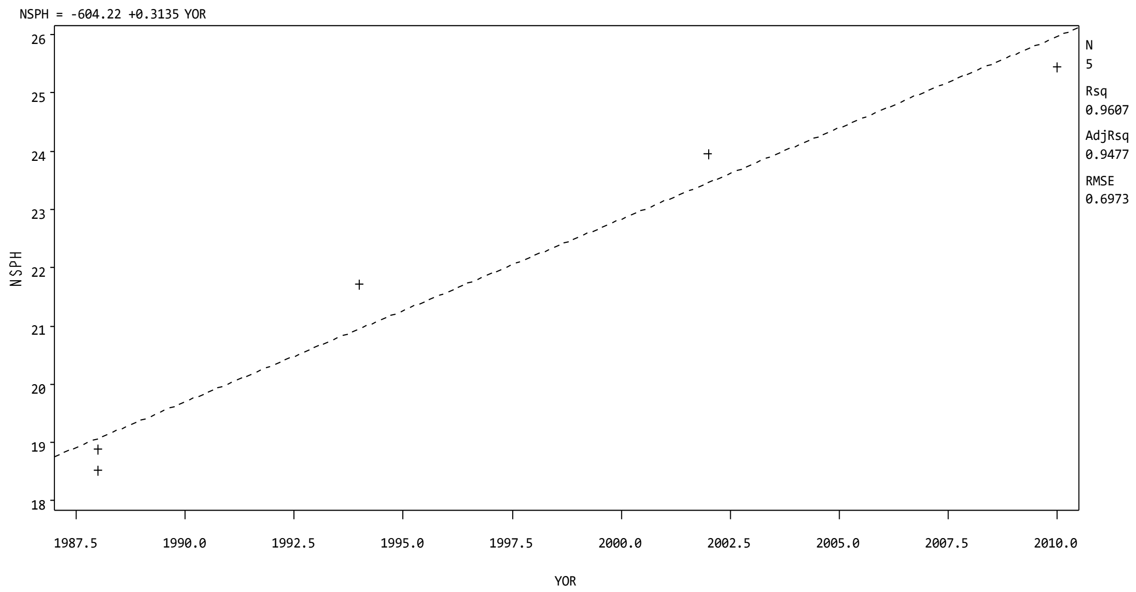

Figure 05. Relationship between mean number seed per head (capitulum) of 5 Noug varieties and the year of release expressed as number of years since 1988

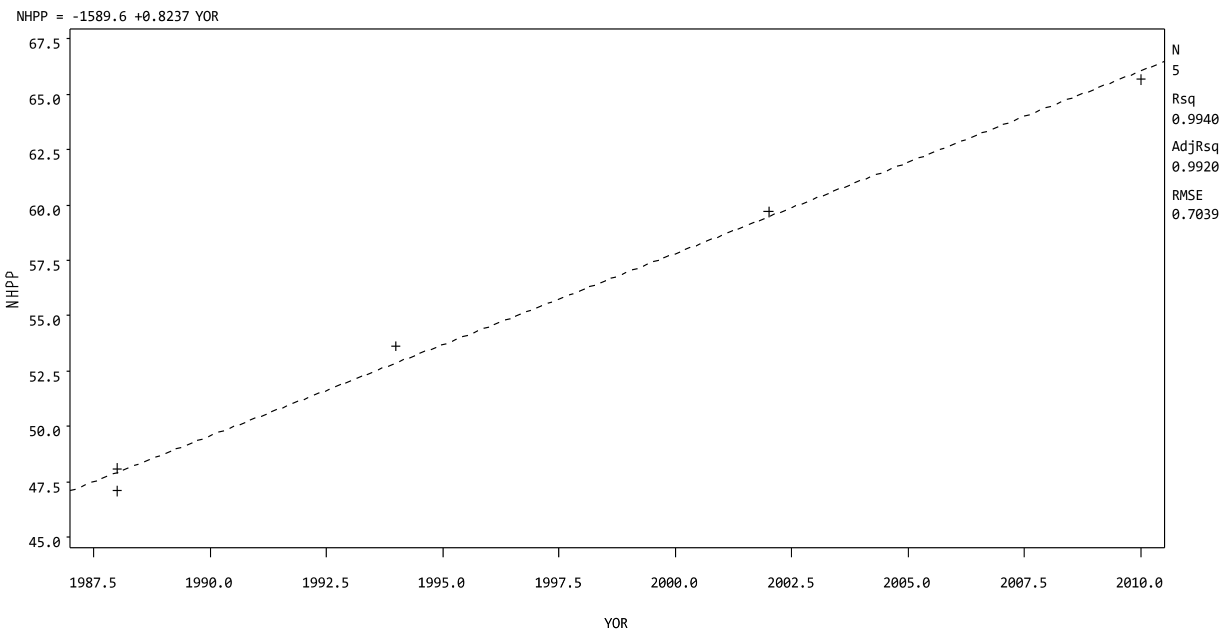

Figure 06. Relationship between mean number head (capitulum) per plant of 5 Noug varieties and the year of release expressed as number of years since 1988

Change in Phonological and morphological traits

The analysis of variance revealed that phonological traits had very significant ($P \leq 0.01$) differences between locations, interaction and among the varieties. A combined analysis revealed significant differences between varieties for phonological traits (Table 02, Table 03). Days to flowering and days to mature in this study showed varieties take from 82.81 to 101.93 days to flower and from 142.81 to 159.06 to mature with mean values 91.41 and 150.85, respectively. The modern varieties have taken medium to short days to attain flowering and physiological maturity. Despite significant phonological development phases, regression of phonological growth traits showed slopes with negative tendency but insignificant from zero. Yifru and Hailu (2005) reported that both old and modern varieties had similar days to physiological maturity. Ribeiro et al. (2008) also found a negative genetic gain for the number of days to 50% flowering in common bean. Nonetheless, Cox et al. (1988), Perry and D'Antuono. (1989) and Tahir et al. (2000) indicated that modern wheat varieties were earlier maturing than the oldest ones. Fikre et al. (2012) reported that all phonological traits were significantly ($P \leq 0.01$) and negatively associated with grain yield. Consistent results obtained by Ramteke et al. (2010) and Faisal et al. (2006) showed that grain yield was negatively related to phonological traits. Demissew (2010) noticed that phonological traits showed significant increment over years of soybean improvement. However, Kebere et al. (2006) and Tamene et al. (2008) found a non-significant increase in days to maturity in haricot bean and Fababean.

The combined analysis of variance showed that morphological traits exhibited very significant ($P \leq 0.01$) differences between locations and varieties. However, location x variety interaction was non-significant for morphological traits. Plant height in noug varieties currently evaluated over locations showed a respective range from 91.29 to 129.83cm (Table 03) with mean values of 100.90cm. Number of primary branches in noug varieties currently evaluated over locations showed respective range from 7.70 to 10.14 (Table 03) with mean values of 9.29. Highly significant differences between varieties exist for these traits. Ersullo et al. (2016) also reported significant ($P \leq 0.01$) differences among the locations and variety for plant height and primary branches in linseed. Belete et al. (2017) also noticed that the average number of primary branches and secondary branches was 2.40 and 5.38, respectively. Kebere et al. (2006) reported an inconsistent slow reduction in plant height from the older to the newer varieties in common beans.

IV. Conclusion

Information on the genetic advance obtained over time from a breeding program is useful for development of effective and efficient breeding strategies for further improvement. The present study revealed that breeding has significantly improved grain yield potential of noug through subsequent release of new varieties over the past 22 years. The mean grain yield of all noug varieties over the four locations was 711.62 kg ha^{-1}, and the range was 524.0 kg ha^{-1} to 884.32 kg ha^{-1}. The superior of the variety with the highest yield, Ginchi accounts for a 360.29 kg ha^{-1} or 68.75% increase compared to the local variety and older variety. The annual genetic gain made was 10.36 kg ha^{-1} (1.58 % $year^{-1}$). In general, grain yield has increased from old varieties to new varieties over the past three decades of noug genetic improvement in Ethiopia. This suggests that the potential for noug grain yield has not reached the plateau in Ethiopia. The oil content also showed significant increment over the past 22 years with annual gain of 0.34% on dry weight basis per year, representing a relative annual gain of 0.88% over 22 years of noug breeding. Similar trends were observed for the biomass yield per hectare over the last 22 years of noug improvement. Biomass yield improved significantly by 8.57 kg ha^{-1} (0.34% $year^{-1}$). Biomass yield, grain yield and harvest index changed with the year of variety release in a similar manner but plant height showed UN even reduction from older to recent varieties.

Generally, research efforts were made for the last three decades and brought considerable improvement in genetic potential and agronomic management of noug varieties. Although the productivity has been significantly increased, dissemination of seeds of improved varieties is very low due to the limited amount of seed produced by few public research institutions. However, if improved seeds and associated technology packages are popularized and made available to the farmers in major noug producing areas of the country, the contribution to the national economy and improvement in the livelihood of the farmers would have been very high. Ethiopia is known for its large genetic base of noug which can develop improved varieties targeting high yield, oil content, and other quality traits.

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However, this enormous potential is not yet exploited due to lack of robust breeding program compared to other crops that allow collection, characterizing, evaluating, and identifying desirable traits for genetic improvement. Furthermore, existing conventional hybridization technique is time taking, laborious, and many of the desirable quantitative traits are highly influenced or masked by environmental effects. Incorporation of molecular plant breeding methods has paramount importance in identifying the target genes and using desirable traits of diverse genetic resources of the country for sustainable development of improved varieties.

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