



Performance of groundnut (*Arachis hypogaea*) cultivars for higher productivity in hilly ecosystem

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ABSTRACT

Low productive cereals (rice and maize/mixed cropping) in the *Jhum* degraded abiotic stressed soils (from acidity and moisture deficit) of rainfed hilly ecosystem of Northeast India (NEI) restrict jhumias socio-economic upliftment. Shift in cropping pattern to stress-tolerant groundnut cultivars may provide an option in such a situation. We evaluated the performance of 26 improved cultivars of groundnut for four consecutive years (2013-2016) in terms of suitable agronomic and physiological traits for higher productivity in such soils under rainfed hilly ecosystem of NEI (Manipur) and compared their performances with one popular local check (JL-24). Few improved cultivars (GG-21, TG 37-A, GG-11, TKG-19-A, ICGV-86590 and ICGS-76) yielded significantly ($P<0.05$) higher (2.72 to 3.35 t/ha) than the local check (2.09 t/ha), primarily because of their better agronomic (leaf area and root dry weight) and physiological (nodulation, chlorophyll and proline contents) traits. Higher agronomical and physiological attributes also led higher production of biomass (above and below ground) than other cultivars. More carbon addition from higher biomass of these cultivars will help in restoration of soil health while higher pod productivity will improve socio-economy of the jhumias. These few selected, sensitive agronomic and physiological traits, thus, can be explored for selection of suitable groundnut cultivars, highly productive yet adaptive and restorative to *Jhum* degraded acid soils in the rainfed hilly ecosystem of NEI as well as in other such similar agro-ecological regions.

Key words: Agronomical traits, *Jhum*, North East India, Physiological traits, Rainfed groundnut

India is the second-largest producer (7.40 mt annually) of groundnut (*Arachis hypogaea* L.), only next to China and among the major oilseed producing crops in India, groundnut alone shares 42% of production (Singh *et al.* 2018). In Northeast India (NEI), groundnut is gaining popularity as an important oilseed crop in the acidic hilly soils, which were once under the cultivation of low productive traditional cereals. The fragile hilly ecosystem of Eastern Himalaya is vulnerable to climate change with extremely degraded hill soils from shifting cultivation (*Jhum*) led vegetation burning and deforestation, acidity and severe water erosion. To sustain the food requirement of the burgeoning population in the fragile hilly rainfed uplands, improvement in agricultural productivity through adoption of improved crop cultivars suitable to targeted environments is the need of the hour (Singh *et al.* 2014). Diversification of cropping pattern by the inclusion of legume crops like groundnut in the existing cropping pattern (rice/maize/mixed cropping) in the degraded sloppy uplands assures better nutritional security by providing vegetable proteins and edible oils (Bhadana *et al.* 2013, Das *et al.* 2016, Ansari *et al.* 2017a, Das *et al.* 2018).

Growing stress-tolerant cultivars in a degraded

ecosystem with marginally available inputs to plants represent the strategy of “tailoring the plant to fit the soil” in contrast to the older strategy of “tailoring the soil to fit the plant” (Foy 1993). Such strategy, however, needs identification of suitable cultivars adaptable to stress conditions and/or having improved resource use efficiencies. The multiple agronomical and physiological traits are considered for evaluation of high yielding groundnut cultivars (Tajima *et al.* 2008). In the hilly (*Jhum*) degraded acid soils of Eastern Himalayan ecosystems, the potential of groundnut cultivation remains unexplored due to lack of adequate information on suitable cultivars with adaptive traits. We attempted the present study to identify suitable cultivars with such adaptive agronomic and physiological performance with higher production efficiency under the degraded soils of a rainfed hilly ecosystem of Eastern Himalaya.

MATERIALS AND METHODS

Experimental site and treatment details: The experiment was conducted for four consecutive years (2013-2016) in the hill (*Jhum*) soils at Langol farm of ICAR Research Complex for NEH Region, Manipur Centre, Imphal, India (24° 49' N latitude, 93° 55' E longitude and 786 m above MSL altitude). The climate in the experimental site is humid subtropical with mean monthly minimum and maximum temperatures during the study period (May to October)

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varied widely from 18.6-32.8°C while mean annual rainfall varied from 818.7 mm (in 2013) to 1852 mm (in 2016). Mean monthly sunshine hours varied from 2.6-5.8 hr, while average relative humidity varied from 62-93%. The soils of the experimental site was sandy clay loam (sand 52.2%, silt 14.6%, and clay 33.2%) in texture, acidic in reaction (pH 4.9), high in organic carbon (Walkley and Black, 1.51%), low in available nitrogen (alkaline permanganate N, 185.5 kg/ha), available phosphorus (Bray I P, 8.1 kg/ha) and available K (115.5 kg/ha) contents. The experiment was laid out in randomized block design with 26 improved groundnut cultivars and replicated thrice. In addition, a popular local cultivar JL-24 as a check also included. The improved cultivars belonged to two major groups, viz. 9 early maturing while 17 were medium to late maturing cultivars. The seeds were sown during the first week of May and harvested from late September to mid-October. The experimental site was well managed and free from weeds, diseases, and insect pests' incidences.

Measurement of growth attributes chlorophyll and proline contents: Leaf area of five randomly selected plants was measured by passing the leaves through a LI-3100 leaf area meter (LiCor, Lincoln, NE, USA). The plant biomasses were dried at 65±1°C till the constant dry weight was achieved in a hot air oven. Chlorophyll content index (CCI) was measured with chlorophyll content meter (CCM-200 plus, Optis Sciences Inc., USA) at 75 DAS in fresh leaves in standing plants. Proline content of the freshly collected leaves was estimated at 50 DAS by the method of Bates *et al.* (1973) and the proline contents were expressed in µM/g of fresh leaf weight.

Nodule count and seed quality: Five random plants from each plot were dug out by breaking the rhizospheric soils around the plants up to a depth of 50 cm with a hand hoe at 75 DAS. In the laboratory, samples were kept in sieves (mesh size 0.25 mm) and washed with water to remove the soil particles. The nodules on the roots were separated and those that broke off during the course of washing were also picked up for the final count. The seed quality (oil and protein) was estimated by using near-infrared spectroscopy (NIRS), with Infratec-1241 seed analyzer (FOSS, Denmark) and software package IRIS 2.X (ISW 2.01), calibrated for the present experiment against conventional wet laboratory analysis.

Statistical analysis: The data for agronomic, physiological and quality traits were analysed using analysis of variance (ANOVA) of randomized block design (RBD) in SPSS v.20 software. Statistical significance was set at an alpha level of 0.05. Means were compared by the least significant difference (LSD) test if the *f*-value was significant. Principal component analysis (PCA) was performed to the 21 variables of agronomical, physiological and quality characters. The PCA and cluster analysis were carried out using SPSS v.20 software.

RESULTS AND DISCUSSION

Genotypic variation on growth and physiological

attributes: Dry biomass production of 75 days old crop varied widely among the cultivars (118.8 to 184.3 g/m²) across the maturity groups. Among the improved cultivars, ICGS-76 produced the highest biomass (184.3 g/m²) and was comparable with the local check (JL-24: 156.4 g/m²) (Table 1). Active nodule (pink or red in colour) counts in roots varied widely among the cultivars: 14.9 in GG-13 to 42.8/plant in ICGS-76 at 75 DAS (Table 1). The highest nodulating improved cultivar ICGS-76 recorded a 2.2-fold increase in nodulation over local check (JL-24: 18.7/plant). The CCI among the cultivars also varied significantly (*P*<0.05) from 22.5 (in Tirupati -4) to 30.6 (ICGS-76) (Table 1). Some of the improved cultivars had significantly (*P*<0.05) higher CCI than local check (CCI: 24.8). However, differences in maturity of duration among the cultivars did not affect the CCI, evidenced from comparable CCI among the early group: 26.4-27.3 (in med to long duration cultivars). Accumulation of proline, a stress indicator to drought tolerance also varied widely (CV: 66.8%) across the improved cultivars ranged from 3.1 (ICGV-88448) to 28.1 µM/g tissue (AK-159). Few improved cultivars, viz. AK-159, HNG-69, FeE SG-10-1 and ICGS-5 accumulated 6-8 fold higher proline level than the local check (JL-24: 3.8 µM/g tissue). The root dry weight (RDW) showed significant (*P*=0.05) differences among the cultivars at various growth stages and as the crop grows old (25 to 100 DAS), RDW also increased consistently across all the cultivars (Fig 1). The maximum RDW was measured in improved cultivars of ICGS-76 followed by ICGV-86590, B-95 and Tirupathi-4 while other cultivars had significantly less RDW, comparable to local check (JL-24) in all the growth stages.

Significant genotypic variation responsible for the expression of differential morphological and physiological traits in groundnut cultivars was also reported earlier (Misra *et al.* 2000, Misra 2004). The genetic make-up responsible for higher growth and better physiological attributes may help in improving adaptive capacity in abiotic stressed environment (degraded soil) for achieving optimal productivity. Variation in growth and physiological traits particularly, LAI, root growth and dry matter accumulation among the groundnut cultivars resulted in significant differences in yield attributes responsible for producing pod yield (Olayinka and Etejere 2015). The effective leaf area in particular of the improved cultivars positively influenced two major physiological traits responsible for photosynthetic efficiency and nitrogen fixation cum accumulation: chlorophyll content (*r*= +0.424*, *P*<0.05) and root nodulation (*r*= +0.642*, *P*<0.01). This was evident from the cultivars ICGS-76 and ICGV-86590 with maximum LAI (>3.0) had significantly higher CCI and nodulation than other cultivars. A significant positive correlation between RDW and LAI (*r* = 0.61, 0.69, 0.74, 0.78 at 25, 50, 75 and 100 DAS, respectively; *P*<0.05) affirms cultivars with higher RDW had more LAI and also accumulated more biomass. Similarly correlation between RDW and DBP (*r*= 0.74, 0.70, 0.75 and 0.73 at 25, 50, 75 and 100 DAS, respectively; *P*<0.05) reaffirms the cultivars RDW had significant influence on DBP. We observed growth

and physiological performances including root growth of some of the cultivars like ICGS- 76, ICGV-86590 and TKG-19-A were exceptionally superior over other improved cultivars and popular local check JL-24. Wissuwa and Ae (2001) also made a similar observation that variation in root hair and root growth in different stages of groundnut is cultivar specific and is one of the desirable traits to select stress tolerant cultivars.

Genotypic variation on yield and shelling percentage: The genotypic variation of groundnut had a significant ($P<0.05$) influence on yield attributes (seed weight/m²) and as a result, wide variation (CV: 27.9%) in these attributes were observed among the cultivars (Table 1). The seed weight as one of the major yield attributing characters also

varied the most (CV: 26.5-28.3%) among the cultivars. Few improved cultivars ICGS-76 and ICGV-86590 in particular produced significantly ($P<0.05$) higher amount of seed per unit area over other 24 improved cultivars and was 63-87% higher than local check (JL-24: 130.6 g/m²) as well. Due to variation in yield attributes, dry pod yield per hectare also varied widely (CV: 19.0%) among the cultivars (Table 1). ICGS-76 and ICGV-86590 produced 2.9-3.35 t/ha pod yield and also other improved cultivars, viz. ICGS-5, TKG-19 A, TG-37-A, GG-11 and GG-21 produced 2.49 to 2.72 t/ha, significantly ($P<0.05$) higher over the check JL 24 (2.09 t/ha). Similarly, shelling percentage of the pods among the cultivars significantly varied from 45.1 to 72.6%, with only ICGS-76 and ICGV-86590 could able to surpass shelling

Table 1 Effect of genotypic variation on physiological, yield and quality attributes of groundnut (Mean of 4 years)

Cultivar	DBP (g/m ²)	Nodules/ plant	CCI	Proline content (µM/g tissue)	Seed weight (g/m ²)	Protein content (%)	Oil content (%)	DPY (t/ha)	Shelling (%)
<i>Early maturing cultivar</i>									
GG-7	163.4	28.8	28.0	4.8	143.7	31.1	53.2	2.20	64.1
GG-8	165.9	36.4	29.2	4.4	154.4	30.0	52.3	2.34	65.9
AK -159	141.5	33.8	26.4	28.1	124.0	31.3	45.4	2.03	60.9
SG-99	146.8	16.4	30.0	8.3	157.8	29.7	52.6	2.39	66.1
OG-52-1	134.5	27.6	25.6	4.0	155.3	30.1	50.1	2.36	65.7
ICGV- 86590	183.1	38.5	28.4	19.2	213.5	29.9	53.0	2.90	72.6
FeE SG-10-1	145.7	18.5	22.7	20.1	129.9	29.4	51.5	2.13	61.8
ICGS-5	119.3	24.0	22.8	23.6	177.5	29.1	49.0	2.56	68.8
T G-37-A	135.6	15.5	24.2	18.7	171.0	30.5	52.5	2.49	68.0
Group average	148.4	26.6	26.4	14.6	158.6	30.1	51.1	2.4	66.0
<i>Medium to late maturing cultivar</i>									
BG-3	145.0	16.2	27.9	21.2	72.4	29.5	50.9	1.52	45.1
Tirupati -4	146.5	30.1	22.5	18.5	94.1	30.3	53.8	1.60	57.6
GG-11	145.7	34.2	25.3	9.7	150.9	30.1	52.5	2.51	64.7
GG-16	152.7	37.5	29.5	20.2	172.9	29.6	51.2	2.31	68.4
ICGS-76	184.3	42.8	30.6	23.8	245.1	30.1	53.5	3.35	72.2
GG-13	156.5	14.9	26.5	9.3	138.8	30.3	53.4	2.16	62.9
GG-20	157.1	15.8	24.2	3.9	150.9	30.2	53.9	2.32	65.3
M -13	118.8	18.0	26.8	7.5	144.7	30.3	51.6	2.22	64.5
B-95	127.6	20.5	30.1	5.1	82.4	30.5	53.9	1.46	57.7
ICGV-88448	119.5	28.7	27.2	3.1	93.7	29.6	54.0	1.75	54.2
HNG-69	178.5	19.0	24.3	21.1	91.1	30.0	52.8	1.69	52.9
CSMG 84-1	131.8	30.7	29.3	14.4	138.4	30.6	54.2	2.18	62.3
GG-21	152.7	24.8	26.0	4.3	168.2	30.0	49.5	2.49	67.4
TKG-19-A	151.1	24.8	26.4	6.4	192.5	31.4	49.6	2.72	70.4
NRCG-CS-281	137.8	22.2	29.4	11.6	159.8	30.5	54.6	2.34	66.3
GG-14	130.0	16.8	29.6	7.7	102.0	30.5	53.4	1.84	53.6
Girnar-2	139.8	33.5	28.9	9.7	115.6	29.6	52.7	2.15	53.3
Group average	145.6	25.3	27.3	11.6	136.1	30.2	52.7	2.2	61.1
JL -24 (Check)	156.4	18.7	24.8	3.8	130.6	30.5	55.1	2.09	62.0
LSD (P=0.05)	15.4	1.5	4.7	1.1	19.0	NS	1.9	0.18	5.6

DBP, dry biomass production (75 DAS); CCI, chlorophyll content index (75 DAS); DPY, dry pod yield.

percentage of above 72%. The efficiency of conversion of assimilates into pod or seed; however, vary due to genetic composition and variability in the suitability of the cultivars to the growing environment (Nautiyal *et al.* 2012, Singh *et al.* 2018). Differential root growth response in the same stressed environment (degraded soil) exhibited by our cultivars might have influenced water and nutrients uptake required for plant growth and yield attributes and thus, contributed the significant variation in pod or seed yield production (Wasson *et al.* 2012). Poor root growth and inferiority in other important physiological attributes (e.g. LAI, nodulation, etc.) with poor yield attributing traits including low harvest index might be one of the reasons for 38-60% less productivity (pod yield) in local check (JL-24) over high yielding improved, more adaptive (higher proline content) cultivars ICGS-76 and ICGV-86590 to stress environment. Shelling percentage is mostly influenced by genotypic behaviour, particularly pod characters (pod size, volume, kernel weight and other residual) of cultivars as well as the availability of calcium (Ca) in the soil (Misra 2004). Therefore, the wide variability in shelling percentage (45-72%) among the cultivars was mostly contributed by the genetic variation led differences in pod characters, including seed yield per pod.

Genotypic variation on quality: One of the important criteria for choosing suitable groundnut cultivar is its oil and protein contents in seed. We observed significant ($P < 0.05$) variation in oil content (45.4-55.0%) while the protein content among the 26 improved cultivars varied marginally (29.1-31.4%) (Table 1). Barring few cultivars, the seeds in majority of them had 53-55% oil contents against 55.1% in local check (JL-24). Similarly, many improved cultivars had comparable protein content in seed (30-31%) with the local check (30.5%). The genetic composition of cultivars primarily controls the seed quality (oil and protein formation) (Misra 2004, Ansari *et al.* 2017b) and this might have made significant differences in oil content in particular among our groundnut cultivars. Variability in

geographical location, crop season, habit group, soil fertility, moisture availability and maturity of crop at harvest further contributes the differences in oil and protein contents (Misra *et al.* 2000, Misra 2004).

Principal component analysis: The cultivars analyzed were dispersed onto three main components on the rotated space scatter plot of the PCA scores, indicating a large variability. The cumulative variance accounted for overall cultivars was 45.5, 12.7 and 9.8% for components 1, 2 and 3, respectively (Fig 2). The cumulative variance explained by all the components was 68.0% (Fig 2). The rotated components Eigen vector matrix showed that the traits more positively correlated with the first PC component were those related to the pod yield and other agronomical and physiological traits (nodules, chlorophyll content index, proline content, seed weight, 100 seed weight, protein content, oil content, shelling percentage, root dry weight, dry biomass production, leaf area index, dry pod weight). The components were grouped together in rotated space (Fig 2) and from the figure, it can be inferred that the said attributes are important for the higher production efficiency of groundnut in hill (*Jhum*) degraded land of Eastern Himalayan Region.

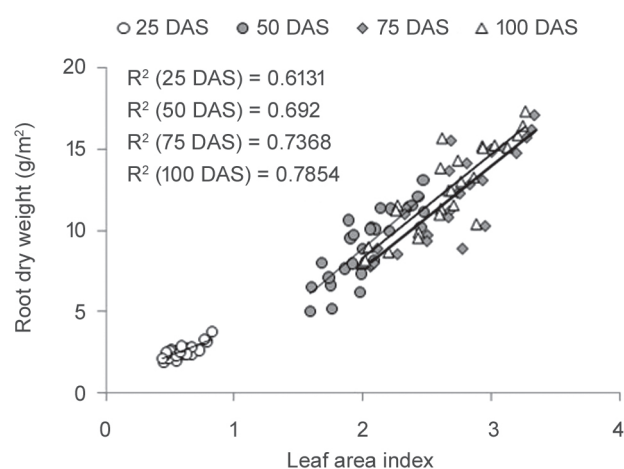


Fig 1 Graphical representation of the significantly positive correlation of root dry weight and leaf area index At 25, 50, 75 and 100 DAS across the 27 cultivars.

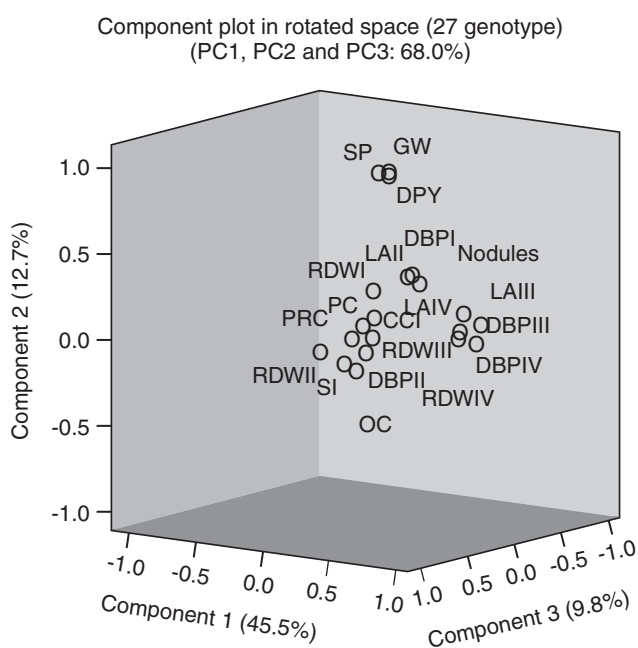


Fig 2 Principal component analysis for assayed variables (21 variables) in rotated space. Nodules, CCI- chlorophyll content index, PRC- proline content, GW- seed weight, SI- 100 seed weight, PC- protein content, OC- oil content, shelling percentage, RDWI- root dry weight at 25 DAS, RDWII- root dry weight at 50 DAS, RDWIII- root dry weight at 75 DAS, RDWIV- root dry weight at 100 DAS, DBPI- Dry biomass production at 25 DAS, DBPII- Dry biomass production at 50 DAS, DBPIII- Dry biomass production at 75 DAS, DBPIV- Dry biomass production at 100 DAS, LAII- leaf area index at 25 DAS, LAIII- leaf area index at 50 DAS, LAIII- leaf area index at 75 DAS, LAIIV- leaf area index at 100 DAS, DPY- Dry pod weight.

It can be concluded from the study that some HYVs, viz. ICGS-76, ICGV-86590, TKG-19-A, ICGS-5, TG 37 A, GG-21 and GG-11 have well adaptability in the hill (*Jhum*) degraded strong acid soils of hilly ecosystem of Eastern Himalaya. Better agronomic and physiological traits of these cultivars helped them to withstand multi-ferrous abiotic stresses (soil degradation from Jhuming, acidity and moisture) and thus, they could able to produce higher dry pod yield.

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