Response of groundnut promising lines to various environments

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Abstract. The aims of this study was to evaluate the response of groundnut promising lines grown in various environments. A number of 18 groundnut lines and 2 checked cultivars were grown in 3 different environments i.e. lowlands with heavy and loamy soil texture at Ngawi and Banyuwangi Districts, and dry alkaline soils at Tuban District. A randomized block design with three replicates was applied in each site. Each genotype was planted in a 2 m x 5 m plot size with plant spacing of 40 cm interrows x 10 cm intrarow, 1 seed/hole. The basal fertilizer of 250 kg/ha composite NPK Phonska was applied at planting time. Location (site), genotype as well as its interaction significantly influenced the growth and yield variables. Four lines gave good yields at all sites i.e. BK10/LG5-295-50, BK1/LG5-37-64, BK1/LG5-B13-29-6, and BK1/LG5-B13-6-1. Those four lines were less stable with its average pod yields were 4.0 t, 4.0 t, 3.9 t, and 4.0 t dry pods/ha consecutively. Those pod yields were equal that those of checked cultivars Katana 1 and Hypoma 1. Instead of producing high pod yields, those four lines are resistant to leaf spot and rust diseases, so are merit to be proposed as newly superior cultivars.

1. Introduction
In Indonesia, groundnuts (Arachis hypogaea L.) belong to palawija crops or belong to dryland food crops. Groundnuts are successfully cultivated in various environments (agro ecologies) such as in wetlands during dry season, in drylands during wet or early dry season, or in rainfed areas, when water availability does not enough for maize or soybean crops. In other words, groundnuts are mostly grown under rainfed condition as also occur in Ethiopia [1] and Zimbabwe [2]. The presence of abiotic and biotic constraints in every agro ecology at any planting area and planting season results in various levels of production and productivity. Therefore, the availability of cultivar with high adaptability, stability, and productivity to various environments is a priority of the works undertaken nowadays. The national demand of groundnut approximately increases by 4.4% annually because of vast progress of peanut-food base industry; meanwhile the production increases at around 2.5% annually. This means there is a wide gap between demand and supply, and the gap has been met by importing peanuts from overseas. There is a window of opportunity to reduce the yield gap i.e. by increasing production. Some efforts are available i.e. growing high productivity cultivar, optimizing the growing environments through improving cultural practices [3].

A series of abiotic and biotic factors constrains groundnut production. The main biotic constraints are foliar diseases and bacterial wilt, and the most prevalent foliar diseases are late leaf spots caused by Phaeoisariopsis personata (Berk & M.A. Curtis) van Arx, and rust caused by Puccinia arachidis Speg [4]. The yield loss up to 60% occurs when these foliar diseases infected the crops [5]. Despite the
success in eradicating the fungal diseases, the application of chemical fungicide will increase farmer’s expenses to the crops, especially for smallholder farmers. It has been known that developing new cultivar with high productivity as well as resistant to foliar diseases is the least inexpensive and effective strategy to obtain high production in the farmer’s level. The breeding program in Indonesia considers the resistance to these foliar diseases is included as one of parameters in developing new cultivars since 40 years ago [6]. The released cultivars with high resistance to leaf spot and rust were produced through recombining genes or crossing between the selected parents based on breeding objective or project concept [7] i.e. cultivars or genotypes or local cultivars with sound resistance to rust and leaf spot diseases as well as high productivity. The objective of the research was to find out the performance of promising lines, to test their yield potentials and stability under various environments.

2. Methods

A number of 18 groundnut promising lines and 2 checked cultivars were evaluated their responses to various environments. Those environments were created from various components as presented in Table 1. The checked cultivars were Hypoma 1 and Katana 1, where Hypoma 1 is released cultivar tolerant to rust and leaf spot diseases, and Katana 1 is recent released cultivar with high productivity and tolerant to bacterial wilt caused by *Ralstonia solanacearum*.

**Table 1.** Sites characteristics for testing the yield performance of groundnut genotypes.

| Site (District) | Altitude (masl) | Season       | Year | Agro-ecology | Climate type | Soil type |
|----------------|----------------|--------------|------|--------------|--------------|-----------|
| Ngawi          | 104            | Early dry season | 2011 | Wetland      | C            | Vertisols |
| Banyuwangi     | 37             | Early dry season | 2011 | Wetland      | C3           | Regosols  |
| Tuban          | 11             | Mid of dry season | 2012 | Wetland      | D3           | Alfisols  |

The experiments applied a randomized block design with three replicates in each site. Each genotype was planted in a 2 m x 5 m plot size with plant spacing of 40 cm x 10 cm, 1 seed/hole. An amount of 250 kg of NPK composite fertilizer/ha was applied at sowing date. Weed controls were undertaken 2 times i.e. on 15 and 35 days after sowing (DAS). Additional weed pickings were undertaken at any time after 50 DAS to remove the unwanted plants. Pests and nontarget diseases were controlled by applying chemical pesticides. Irrigation was applied five times i.e. at sowing date, flowering (25-30 DAS), pod setting (45-50 DAS), pod filling (60-70 DAS), and 4 days before harvesting. The observations on number of filled and empty pods, dry pods weight, 100 seed weight, plant height, fresh haulm weight, pods and seeds weight were undertaken on five sampling plants. Fresh and dry pods yield and numbers of wilting plants caused by *Ralstonia solanacearum* were observed on plot basis. The dry pods yield was then extrapolated on a per-hectare basis. The shelling out-turn (%) was calculated as (kernel or seeds weight/pods weight) × 100 [8]. The incidence of leaf spot and rust diseases were observed at 95 DAS, and the diseases severity was scored using 1-9 scale where 1=highly resistant, 2-3 = resistant, 4-5 = moderately resistant, 6-7 = susceptible, and 8-9 = highly susceptible [9]. The general combined analysis of variance for pod yield, yield attributes and vegetative growth traits was conducted using MSTAT-C.

The stability test [10] and genotype adaptability [11] was examined base on the following model:

\[ Y_{ij} = U_i + B_j + d_{ij}, \quad i=1, 2, ..., g \]

\[ Y_{ij} = \text{the average yield of genotype } i \text{ at } j \text{ site} \]

\[ U_i = \text{the average yield of genotype } i \text{ at all sites} \]

\[ B_j = \text{slope response of genotype } i \text{ to environment} \]

\[ d_{ij} = \text{regression deviation of genotype } i \text{ at } j \text{ site} \]

A genotype with stable pod yields across tested locations is characterized by its regression coefficient \( b_i \) non significantly different to 1 and regression deviation \( S_{di} \) non significantly different to 0, and its average yield is higher than its general average yield of all tested genotypes. The regression coefficient \( b_i \) is also be used as criterium of adaptability levels:

\[ b_i < 1.0 = \text{stability higher than average, specific adaptation to marginal/poor environment} \]
bi = 1.0 = stability equal to average, well adapted to all environments
bi > 1.0 = stability below the average, well adapted in productive environment

Yield stability of a genotype is defined based on regression coefficient (bi), regression deviation (Sdi), and average dry pod yield over tested locations (Eberhart and Russell 1966). The moderate stable is when bi does not significantly equal to 1 or equal to 1, Sdi does not significantly equal to 0 or equal to 0. Under the moderate stable, when the average yield of a genotype higher than its general mean yield so the genotype has broad stability. On the other hand, when the average yield of a genotype is lower than its general mean yield it means that the genotype has poor adaptability in all environments. In term of bi> 1, it means the genotype has poor or low stability, and therefore the genotype is sensitive to environmental changes: under good environment, the genotype will have high productivity and conversely [12]. Genotype with bi< 1 means that the stability of genotype is higher than average. This genotype enables to make a good adaptation under marginal environment such as under drought stress during generative phase or other environmental stresses [12].

3. Results and discussion
Location, genotype, and genotype × location interaction (L, G, G × L, in the rest of the paper) either individually or in combination of these two/three factors were significantly affected pod yield, yield attributes, and vegetative growth except number of productive branches (Table 2). Location (L) contributed as many as 86.9% for pod yield variation while G and G × L only contributed 4.6% and 8.5% on its variation (data were not presented). This figure means that L is the biggest contributor on pod yield variation in three locations. The same phenomena occurred on plant height, 100 seed weight, shelling outturn and the scores of diseases incidence (data were not presented). The dominance role of L to pod yield variation has been reported before in groundnut [1,2,13] and soybean [14]. The presence G × L informs the existence of at least one genotype responded to specific/certain location, while number of productive branches did not significantly different among G, L and G × L. Therefore, pod yield was affected by number of pods/plant.

| Parameters                        | Mean square                      |
|-----------------------------------|----------------------------------|
|                                  | Location (L) | Genotype (G) | G × L        | CV (%)  |
| Plant height                      | 13395.2**    | 15.2 *       | 16.70 **    | 5.8     |
| No. productive branches/plant     | 309.4 ns     | 1.6 ns       | 1.37 ns     | 15.6    |
| No. pods/plant                   | 337.2 ns     | 45.2**       | 39.70 **    | 16.4    |
| Shelling out-turn (%)             | 2129.2**     | 38.5 **      | 35.30**     | 8.3     |
| Dry pods weight (t/ha)            | 72.9**       | 0.40 **      | 0.370**     | 11.0    |
| Weight of 100 seeds               | 3071.0**     | 81.9 **      | 29.30*      | 8.4     |
| No wilted plants/plot             | 885.5*       | 64.1 **      | 64.10 ns    | 93.6    |
| Score for leaf spot at 95 DAS     | 11.8**       | 0.65 *       | 0.51**      | 17.6    |
| Score for rust at 95 DAS          | 35.9**       | 2.5 **       | 1.30**      | 23.2    |

**, * = significant at 0.01 and at 0.05, ns = not significant at 0.05

3.1 Yield Production of Genotypes across Locations
The average pod yield was 2.5 t, 4.2 t, and 4.6 t/ha at Ngawi, Tuban, and Banyuwangi, respectively (Table 3). The lowest pod yield at Ngawi was because of the lowest productivity (27.4 g pods) and smallest seed size (46.3 g/100 seeds) gained per plant. Conversely, the highest pod production in Banyuwangi was supported by the highest productivity (34.2 g pod yield/plant) and biggest seed size (58.7 g/100 seeds). The significant response of G to L was expressed by the wide range of pod yields and pod productivity among locations. All genotypes in Ngawi produced lowest pod yields. High clay
content in Vertisols would be a problem for groundnut crops grown during dry season cropping especially related to the availability of water during pod formation. Since the plants were harvested at 95 DAS at Ngawi, water stress occurred at 45-70 DAS (flowering) and pod development (60-90 DAS) would be limiting the pod yields [3]. The pod yield in Tuban was almost similar to the yield obtained in Banyuwangi, and both were 67.7 and 83.2% higher than that in Ngawi. Based on the results from three locations, it is clear that location governed the growth and yield of groundnut crops. The highest yield in each location was obtained by different genotypes. Genotype BK10/LG5-295-50 gave the highest yield in Ngawi and less dominant in the other two locations. In Tuban, however, the checked cultivar of Katana 1 was the most dominant in yield. Genotype LG5/BK1-240-75 resulted in the highest yield in Banyuwangi.

Table 3. Pod yields of all genotypes and the average pod yields from 3 locations.

| Genotype               | Dry pod yield (t/ha) | Ngawi, Early dry season | Tuban, Mid dry season | Banyuwangi, Early dry season | Average of 3 locations |
|------------------------|----------------------|--------------------------|-----------------------|-------------------------------|------------------------|
| BK10/LG5-295-50        | 3.0 a                | 4.2 b-f                  | 4.7 a-f               | 4.0 abc                       |
| LG5/BK1-240-75         | 2.2 b                | 3.6 f                    | 5.3 a                 | 3.7 b-e                       |
| LG5/BK1-192-72         | 2.5 ab               | 3.9 c-f                  | 4.5 b-f               | 3.6 cde                       |
| LG5/BK1-77-20          | 2.1 b                | 3.6 f                    | 4.7 a-f               | 3.5 e                         |
| LG5/BK10-89-68         | 2.5 ab               | 3.7 ef                   | 5.1 abc               | 3.8 b-e                       |
| BK1/LG5-B13-29-6       | 2.4 ab               | 4.5 bc                   | 4.7 a-e               | 3.9 a-e                       |
| BK1/LG5-B13-12-2       | 2.3 b                | 4.5 bc                   | 4.0 f                 | 3.6 cde                       |
| BK10/LG5-141-60        | 2.2 b                | 3.8 def                  | 4.5 b-f               | 3.5 cde                       |
| BK1/LG5-B13-6-1        | 2.7 ab               | 4.0 c-f                  | 5.2 ab                | 4.0 abc                       |
| BK1/LG5-37-64          | 3.1 a                | 4.5 bcd                  | 4.3 def               | 4.0 a-d                       |
| BK1/LG5-39-65          | 2.4 ab               | 3.9 c-f                  | 4.7 a-e               | 3.7 b-e                       |
| BK1/LG5-34-63          | 2.4 ab               | 4.2 b-f                  | 4.6 a-f               | 3.7 b-e                       |
| LG5/BK1-182-71         | 2.4 ab               | 4.0 c-f                  | 4.4 c-f               | 3.6 cde                       |
| BK10/LG5-130-57        | 2.7 ab               | 4.4 bcd                  | 4.5 c-f               | 3.9 a-e                       |
| B/A-171-69-201         | 2.7 ab               | 4.5 bcd                  | 4.1 ef                | 3.8 b-e                       |
| BK1/LG5-32-14          | 2.6 ab               | 4.1 c-f                  | 4.3 def               | 3.7 b-e                       |
| BK1/LG5-B13-32-7       | 2.4 ab               | 4.3 b-e                  | 4.3 def               | 3.7 b-e                       |
| B/A-171-69-17          | 2.1 b                | 4.0 c-f                  | 4.3 def               | 3.5 de                        |
| Katana 1               | 2.7 ab               | 5.4 a                    | 4.7 a-e               | 4.3 a                         |
| Hypoma 1               | 2.7 ab               | 4.9 ab                   | 4.9 a-d               | 4.2 ab                        |
| Average pod yield      | 2.5 p                | 4.2 q                    | 4.6 q                 | 3.8                            |
| LSD 0.05 for yield/location *) | 0.503               |                          | 0.47                  |                                |

Numbers followed by the same letters in each column did not significantly different based on Duncan range test at 5%; *) for average yield in each location.

The average pod yield of each genotype over three locations were between 3.5-4.3 t/ha, with seven, 11, and two genotypes with higher, equal, and lower than the average yield (Table 3). All genotypes were resistant to leaf spot and rust infections as indicated by score of around 3 for both foliar deseases (data not shown). The checked cultivars (Katana 1 and Hypoma 1) were still the most superior cultivars compared to those of 18 tested genotypes. The highest yield of 4.3 dry pods/ha was obtained by Katana 1. Genotype BK10/LG5-295-50, BK1/LG5-B13-29-6, BK1/LG5-B13-6-1, BK1/LG5-37-64, and BK10/LG5-130-57 gave the similar pod yield to both checked cultivars Hypoma 1 and Katana 1. These
high pod yields were contributed by its high number of pods/plant and big seed size when the weight of 100 seeds >50 g [15] where both components were positively correlated to pod yield [15]. Other study showed that pod yield positively correlates to pod yield per plant (plant productivity) and seed size, and negatively correlate to pod moisture content at harvesting time [16]. Moreover, pod yield per plant (plant productivity) was positively and highly direct affected by number of mature pods/plant and kernel yield/plant [17].

Since groundnut crops are grown in a rice-based cropping pattern, the early maturity cultivar at around 90-95 days is preferred. Despite of its short growing period, these genotypes has to fulfill the selection criteria i.e. high shelling outturn (70% or greater) and 100-seed weight in the range 35-40 g [7]. The study showed that all tested genotypes had 41-48% of shelling outturn even though they had bigger seed size i.e. 48-56 g/100 seeds (data not shown). The previous studies showed the positive correlation between kernel yield and shelling outturn [18-19].

3.2 Yield Stability
The mean square of G on dry pod yield was significant (Table 3). This explained the presence of yield variation among genotype. G × L on dry pod yield was also significant (Table 3). It tells that environment had a role in defining pod yield of genotypes.

### Table 4. Average pod yield, regression coefficient and deviation, stability and adaptation of groundnut genotypes.

| Genotype                  | Average pod yield (t/ha) | Regression Coefficient (b) | Regression Deviation (Sb) | Stability | Adapted in environment |
|---------------------------|-------------------------|---------------------------|---------------------------|-----------|------------------------|
| BK10/LG5-295-50           | 4.0 abc                  | 0.76 *                    | 0.054 ns                  | Unstable  | marginal               |
| LG5/BK1-240-75            | 3.7 b-e                  | 1.27 *                    | 0.825 *                   | Unstable  | Productive             |
| LG5/BK1-192-72            | 3.6 cde                  | 0.90 ns                   | 0.072 ns                  | Stable    | marginal-productive    |
| LG5/BK1-77-20             | 3.5 e                    | 1.12 *                    | 0.282 *                   | Unstable  | Productive             |
| LG5/BK10-89-68            | 3.8 b-e                  | 1.06 ns                   | 0.556 *                   | Unstable  | Productive             |
| BK1/LG5-B13-29-6          | 3.9 a-e                  | 1.12 *                    | 0.105 ns                  | Unstable  | Productive             |
| BK1/LG5-B13-12-2          | 3.6 cde                  | 0.94 ns                   | 0.440 *                   | Unstable  | Marginal               |
| BK10/LG5-141-60           | 3.5 cde                  | 1.03 ns                   | 0.095 ns                  | Stable    | Productive             |
| BK1/LG5-B13-6-1           | 4.0 abc                  | 1.04 ns                   | 0.385 *                   | Unstable  | Productive             |
| BK1/LG5-37-64             | 4.0 a-d                  | 0.63 *                    | 0.125 ns                  | Unstable  | marginal               |
| BK1/LG5)-39-65            | 3.7 b-e                  | 1.02 ns                   | 0.136 *                   | Unstable  | productive             |
| BK1/LG5)-34-63            | 3.7 b-e                  | 1.03 ns                   | 0.060 ns                  | Stable    | productive             |
| LG5/BK1-(182-71           | 3.6 cde                  | 0.93 ns                   | 0.045 ns                  | Stable    | marginal               |
| BK10/LG5-130-57           | 3.9 a-e                  | 0.88 *                    | 0.079 ns                  | Unstable  | marginal               |
| B/A-171-69-201            | 3.8 b-e                  | 0.77 *                    | 0.289 *                   | Unstable  | marginal               |
| BK1/LG5-32-14             | 3.7 b-e                  | 0.81 *                    | 0.041 ns                  | Unstable  | marginal               |
| BK1/LG5-B13-32-7          | 3.7 b-e                  | 0.95 ns                   | 0.123 ns                  | Stable    | marginal               |
| B/A-171-69-17             | 3.5 de                   | 1.05 ns                   | 0.061 ns                  | Stable    | productive             |
| Katana 1                  | 4.3 a                    | 1.12 *                    | 0.769 *                   | Unstable  | productive             |
| Hypoma 1                  | 4.2 ab                   | 1.10 ns                   | 0.182 *                   | Unstable  | productive             |
| Average pod yield         |                         |                           |                           |           | 3.8                    |

Numbers followed by the same letters did not significantly different based on Duncan range test at 5%

Some genotypes showed stable and some others were unstable [10-11] (Table 4). The stable genotypes were LG5/BK1-192-72, BK10/LG5-141-60, BK1/LG5-34-63, B/A-171-69, LG5/BK1-182-
71, and BK1/LG5-B13-32-7. These genotypes had lower pod yields than two checked cultivars or any one of checked cultivar as well as lower pod yields than the general average yields (Table 4). The unstable genotypes were BK10/LG5-295-50, BK1/LG5-B13-29-6, BK1/LG5-B13-6-1, and BK1/LG5-37-64 with high pod yields (equal to the yield of checked cultivars). These genotypes were predicted to have good adaptability in various environments or location specific.

4. Conclusion
The significant G × L of most growth components and pod yields proved that genotypes highly various response to environment. Genotype BK1/LG5-B13-6-1, BK1/LG5-37-64, BK10/LG5-295-50, BK1/LG5-B13-29-6, and BK10/LG5-130-57 had high productivity, similar to those of checked cultivars. These genotypes were unstable and adapted to marginal or productive environment. Genotype BK1/LG5-B13-32-7, LG5/BK1-192-72, and LG5/BK1-182-71 were stable with the productivity were lower than the general mean of pod yields and therefore these genotypes showed poor adaptability.

References
[1] Kebede A and Tana T 2014 Sci. Technol. Arts Res. J. 3 (2) 43-46
[2] Savemore N, Manjeru P and Ncube B 2017 Afr. J. Plant Sci. 11 (3) 54-60
[3] Singh A L, Nakar R N, Goswami N, Kalariya K A, Chakraborty K and Singh M 2013 Adv. Plant Physiol. 14 371-465
[4] Mehan V K and Hong N X 1994 IAN 14 8-11
[5] Thakur S B, Ghimire S K, Chaudary N K and Shrestha S M and Mishra B 2013. Int. J. Life Sci. Biotech. Pharmaceutical Res. 2 254-262
[6] Balitkabi 2016 Description of Released Cultivar of Legumes and Tuber Crops. 8 th printed (revision) (Malang: Indonesian Legumes and Tuber Crops Research Institute) p 218
[7] Pasupueilti J, Manohar S S, Deshmukh D B, Chaudhari V, Papaih V and Variath MT 2017 Standard Operating Procedure for Groundnut Breeding and Testing (India: ICRISAT) p 18
[8] Meena H N, Yadav R S 2018 J. Irrig. Drain. Eng. 144 (3) 04018002
[9] Subrahmanyam P, McDonald D, Waliyar F, Reddy L J, Nigam S N, Gibbons R W, Ramanatha Rao V, Singh A K, Pande S, Reddy P M and Subba Rao P V 1995 Screening methods and sources of resistance to rust and late leaf spot of groundnut (India: ICRISAT) p 20
[10] Eberhart S A and Russell W A 1966 Crop Sci. 6 36-40
[11] Finlay KW and Wilkinson G N 1963 Aust. J. Agric. Res. 13 742-754
[12] Fernandez G C J 1992 Proc. Internat. Symp. (Taiwan: AVRDC)
[13] Dolinassou S, Tchiagam J B N, Kemoral A D and Yanou N N 2016 J. App. Biol.Biotech. 4 (01) 001-007
[14] Kuswantoro H, L Ujiarto, A Sulistyo and RT Hapsari 2016 J. Agron. Indonesia 44 (1) 26-32
[15] TPPV [Tim Penilai dan Pelepas Varietas] 2013 Technical Guideline for Composing the Description of Food Crops Cultivar (Jakarta: National Seed Agency)
[16] Rahmianna A A and Purnomo J. 2018 J. Agron. Indonesia 46 (1) 71-80
[17] Ganvit R S and Jagtap P K 2018 Int. J. Curr. Microbiol. App. Sci. 7 (11) 3566-3572
[18] Konlan S, J Sarkodie-Addo, E Asare and M J Kombiok 2013 Afr. J. Agric. Res. 8 (22) 2769-2777
[19] Zuza Jnr E, A Muitia, Amame M I V, Brandenburg R L and Mondjana A M 2017 J. Postharvest Technol. 05 (2) 55-63