Yield gain of groundnut cultivars released from 1950 until 2017

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Abstract. The renewal of the cultivars is believed to contribute significantly to crop yield increased, including groundnut. Indonesia has released 45 improved cultivars from 1950 to 2017. Among those, thirty cultivars were evaluated to assess the yield gain of the crop’s improvements. The period in which the thirty cultivars released divided into five eras, separated every ten years, except between the first and second era. Those cvs planted in Jambegede Res. Sta. during the dry season 2018, were arranged in randomized complete block design, replicated 2 times. Each cv was planted in 6 rows of 2 m length, 50 x 10 cm planting distance, one plant per hill. Two rows were used for destructive samplings, and the rest four rows were harvested for yield and yield components measurements. Data collected consisted of growth rates at four growth stages (plant height, branches number, leaflets number, gynophore number, shoot and root dry weight), pod size, seed size, dry pod yield. All the cultivars were highly varied in yield and yield components variables at harvest. However, there was no variability existence on the observed growth parameters. The exception were on branch and leaflets number at 15 days and gynophore number at 80 days. Cultivars mean dry pod yield of the five classification eras ranged from 1531.4 g-1847.7 g 8m⁻² with yield gain 5.89 g/8 m⁻² or 0.38% year⁻¹.

1. Introduction
Groundnut is an important palawija crop in Indonesia. It serves as a cash crop [1], animal feed, and an important protein source in people diet for its multi nutrients content [3] and very prospective functional food for bioactive compounds content [3]. Despite its high economic importance, the national average yield is still low, i.e. 13.23 ku/ha [4], and the production is only meet 70,5% of the national demand [5].

Groundnut breeding program in Indonesia began in 1950 with the prime objective was bacterial wilt (BW) resistance and yield increased. BW was the most important disease for groundnut cultivation in Java, the main groundnut planting area. Four improved cultivars, i.e. Gajah, Banteng, Kidang, and Macan have been released for the purpose. Those four cultivars last for a long time in farmers’ field, and only after 33 years later new improved cultivars were released, i.e. Rusa, Anoa, Tapir, Pelanduk, and Tupai. Afterwards, as many as 36 improved cultivars were released until 2017. Those following released cultivars, in addition of high yield and BW resistance, breeders added abiotic (acid soil, drought, shading, Fe deficiency) to tolerance and biotic (foliar diseases) resistances, and improved stability and production efficiency and seed quality. That improved cultivar has indirectly resulted in the improvement of national groundnut yield [6; 4]. However, the progress made in those cultivars has not been assessed so far. Evaluation of genetic improvement and the associated changes in agronomic and
physiological traits determining grain yield in crops may help identify traits of potential value for future breeding [7].

Various procedures to estimate genetic progress realized from long-term breeding efforts are reported, one of them is evaluating performance of varieties developed over certain and long periods in common environment regressed over years of varietal release [7; 8; 9; 10; 11; 12].

The study was carried out to assess the progress in yield and yield-related traits made in groundnut cultivars released during 1950-2014. There was no improved cultivar released during 2015-2017, made cultivars released in 2014 were the latest improved cultivars. The released period was divided into five eras, i.e. 1950-1980, 2. 1980-1990, 3. 1990-2000, 4. 2000-2010, and 5. >2010. The first era represented by 4 cultivars, second era by 4 cvs, third era by 6 cvs, fourth era by 7 cvs, and the fifth one by 9 cvs.

2. Materials and Methods
The field evaluation was undertaken in ILETRI Experimental Station at Jambegede (8°10′30″LS, 112°33′32.4″BT, and altitude 335 m, Alfisol and Inceptisol Association) during the dry season on January-May 2018. Total rainfall during the trial was 499 mm in 32 rainy days, and temperature ranged from a minimum of 19°C to a maximum of 32°C.

Thirty groundnut improved cultivars released from 1950 to 2017 (table 1) were evaluated in the study. The experiment was set in a randomized block design replicated 2 times. Each cv was planted in 6 rows of 2 m length, 50 x 10 cm planting distance, one plant per hill. Two rows were used for destructive samplings, and the rest four rows were harvested for yield and yield components measurements. Fertilizers Phonska 300 kg ha⁻¹ + SP36 100 kg ha⁻¹ applied entirely at planting time.

Data measurements were on growth rates at 4 growth stages (juvenile, flowering, maximum vegetative, and full seed) consisted of plant height, number of branches, number of leaflets, number of gynophores, shoot and root dry weight, and pod dry weight. Pod size (g/100 pods), seed size (g/100 seeds), pod yield were recorded on a plot basis. Pod yields were determined from all plants harvested from the plot, sun dried, and reported in kilograms per plot (8m²).

Variance, correlation and regression analyses were performed using Minitab and Excel. Genetic yield potential gains were determined by linear regression of yield, expressed in gram per plot size (8m²), by year of cultivar release (13). DMRT was used for pod yield mean comparisons between cultivars.
| No. | Cultivars             | Pedigree                                      | Year released | Era |
|-----|-----------------------|----------------------------------------------|---------------|-----|
| 1   | Banteng               | Schwarz 21xSpanish 18-38 Eyc.3               | 1950          | 1   |
| 2   | Gajah                 | Schwarz 21xSpanish 18-38                     | 1950          | 1   |
| 3   | Kidang                | Schwarz 21xSmall Japan                       | 1950          | 1   |
| 4   | Macan                 | Schwarz 21/Small Japan                       | 1950          | 1   |
| 5   | Anoa                  | Gajah/ AH.223 (PI 350680)                    | 1983          | 2   |
| 6   | Tapir                 | Kidang x Virginia Bunch Improved             | 1983          | 2   |
| 7   | Kelinci               | Introduction Philipinnes Acc 12              | 1987          | 2   |
| 8   | Jepara                | Local Jepara                                | 1989          | 2   |
| 9   | Badak                 | No 726 x FESR 12                            | 1991          | 3   |
| 10  | Mahesa                | PI 350680 x Kidang                          | 1991          | 3   |
| 11  | Zebra                 | MGS 9-2-5 x NC 3033-4B-9                    | 1992          | 3   |
| 12  | Jerapah               | Local Majalengka x ICGV 86021               | 1998          | 3   |
| 13  | Panter                | ICG 1703                                    | 1998          | 3   |
| 14  | Singa                 | ICG 1697                                    | 1998          | 3   |
| 15  | Bima                  | Local Bima                                  | 2001          | 4   |
| 16  | Kancil                | F334A-B-14 x NC Ac 2214                     | 2001          | 4   |
| 17  | Sima                  | Local Majalengka x ICGV 87165               | 2001          | 4   |
| 18  | Turangga              | OG 69-6-1 x NC Ac 17090                     | 2001          | 4   |
| 19  | Tuban                 | Local Tuban                                 | 2003          | 4   |
| 20  | Bison                 | Kelinci x Gajah mutant                      | 2004          | 4   |
| 21  | Domba                 | Gajah x PI 259747                          | 2004          | 4   |
| 22  | Talam-1               | Jerapah x ICGV 91283                        | 2010          | 5   |
| 23  | Hypoma 1              | Local Lamongan x Tuban                      | 2012          | 5   |
| 24  | Hypoma 2              | Local Lamongan x Tuban                      | 2012          | 5   |
| 25  | Takar 2               | Local Muneng x ICGV 92088                   | 2012          | 5   |
| 26  | Takar 1               | Macan x ICGV 91234                         | 2012          | 5   |
| 27  | Litbang Garuda 5      | Local Lamongan x ICGV 87123                 | 2013          | 5   |
| 28  | Var. Gundul           | Local Gundul Kalimantan                    | 2013          | 5   |
| 29  | Talam 2               | Gajah x ICGV 92088                         | 2014          | 5   |
| 30  | Talam 3               | Gajah x ICGV 92088                         | 2014          | 5   |

3. Results and Discussion

3.1. Variance analyses

Variance analysis of yield and yield components of 30 groundnut cultivars released from 1950 till 2017 showed that all the cultivars were highly varied in yield and yield components variables, except the number of branches Table 2). However, there was no variability existence on the measured growth parameters, the exception was on branch and leaflets no. at 15 days, gynophore number. at 60 and 80 days, the number of filled- and young-pods at 80 days (Table 3). The narrow genetic base of the 30 evaluated cultivars might be contributed to the absence on the most growth parameter variabilities. Among those 30 cultivars, twenty-two cultivars were directly or indirectly derived from Schwarz 21 (Table 1). Moreover, seed and pod characteristics preference were also narrowing the cultivars’
variability. Nevertheless, the requirement for distinct improvement for the newer improved cultivars was expressed in the yield and yield-related traits (Table 2) and abiotic/biotic tolerance (6).

**Table 2.** Mean squares and coefficient of variation of yield and yield components of 30 groundnuts improved cultivars at harvest time.

| Cultivar    | Released year | Plant height (cm) | No. of branches/plant | No. filled pods/plant | Pod weight (g/100 pods) | Seed weight (g/100 seeds) | Pod yield (g/8m²) |
|-------------|---------------|-------------------|-----------------------|-----------------------|-------------------------|---------------------------|------------------|
| Hypoma 1    | 2012          | 47.4              | 6.2                   | 20.0                  | 151.0                   | 55.0                      | 2661.5 f         |
| Bima        | 2001          | 41.2              | 4.7                   | 15.3                  | 139.2                   | 36.2                      | 2467.9 f         |
| Domba       | 2004          | 51.7              | 4.2                   | 19.7                  | 186.6                   | 47.6                      | 2419.0 f         |
| Takar 2     | 2012          | 41.5              | 6.8                   | 21.3                  | 132.7                   | 57.2                      | 2279.7 ef        |
| Talam 2     | 2014          | 42.9              | 7.0                   | 25.8                  | 113.3                   | 47.1                      | 1952.2 def       |
| Takar 1     | 2012          | 48.0              | 6.7                   | 24.2                  | 166.6                   | 67.4                      | 1851.9 ede       |
| Talam 1     | 2010          | 47.0              | 6.5                   | 22.5                  | 119.1                   | 45.7                      | 1839.4 bcde      |
| Badak       | 1991          | 49.2              | 4.0                   | 21.8                  | 141.7                   | 41.5                      | 1704.3 e         |
| Kancil      | 2001          | 42.4              | 5.2                   | 34.0                  | 100.5                   | 44.3                      | 1644.1 abcd      |
| Hypoma 2    | 2012          | 38.3              | 7.0                   | 17.8                  | 146.6                   | 54.3                      | 1623.9 abcd      |
| Gajah       | 1950          | 41.6              | 4.8                   | 28.5                  | 149.7                   | 56.2                      | 1610.5 abcd      |
| Anoa        | 1983          | 46.4              | 5.2                   | 22.7                  | 115.2                   | 47.6                      | 1610.1 abcd      |
| Mahesa      | 1991          | 45.5              | 5.8                   | 28.0                  | 126.0                   | 49.6                      | 1607.2 abcd      |
| Tapir       | 1983          | 42.7              | 6.8                   | 17.7                  | 136.1                   | 54.4                      | 1606.6 abcd      |
| Sima        | 2001          | 40.4              | 4.3                   | 19.0                  | 131.5                   | 40.5                      | 1603.7 abcd      |
| Singa       | 1998          | 54.7              | 4.3                   | 13.5                  | 166.3                   | 43.8                      | 1602.3 abcd      |
| Jerapah     | 1998          | 48.6              | 5.7                   | 24.8                  | 97.2                    | 44.3                      | 1598.1 abcd      |
| Turangga    | 2001          | 61.3              | 4.2                   | 19.2                  | 168.6                   | 43.6                      | 1590.4 abcd      |
| var Gundul  | 2013          | 34.5              | 8.0                   | 22.0                  | 118.3                   | 45.1                      | 1571.6 abcd      |
| Macan       | 1950          | 44.9              | 5.5                   | 23.7                  | 118.3                   | 48.1                      | 1570.0 abcd      |
| Tuban       | 2003          | 47.6              | 5.3                   | 28.3                  | 107.4                   | 43.3                      | 1533.7 abcd      |
| Zebra       | 1992          | 48.5              | 4.2                   | 21.5                  | 157.1                   | 42.6                      | 1530.7 abcd      |
| Bison       | 2004          | 44.9              | 4.8                   | 27.3                  | 110.1                   | 47.8                      | 1528.6 abcd      |
| Kidang      | 1950          | 45.1              | 5.2                   | 20.2                  | 123.3                   | 53.4                      | 1528.6 abcd      |
| Talam 3     | 2014          | 43.4              | 4.5                   | 31.0                  | 110.8                   | 47.8                      | 1481.1 abc       |
| Panter      | 1998          | 47.8              | 4.5                   | 22.2                  | 109.8                   | 42.7                      | 1445.6 abc       |
| Banteng     | 1950          | 46.1              | 4.8                   | 25.7                  | 119.3                   | 50.9                      | 1416.4 abc       |
| Jepara      | 1989          | 35.1              | 5.2                   | 25.3                  | 114.5                   | 50.2                      | 1406.4 abc       |
| Kelinci     | 1987          | 42.8              | 4.8                   | 20.2                  | 139.1                   | 43.7                      | 1406.2 ab        |
| Litbang     | 1991          | 45.1              | 5.2                   | 20.2                  | 123.3                   | 53.4                      | 1528.6 abcd      |
| Garuda 5    | 2013          | 40.3              | 5.2                   | 21.2                  | 106.3                   | 44.1                      | 1359.7 a         |

| MS Squares  | 58.21**       | 2.218ns           | 1035.3                | 41.04                 | 78.35*                 | 219772*                |
| CV (%)      | 13.34         | 9.58              | 9.58                  | 20.77                 | 9.75                   | 16.95                  |

*ns : mean squares non-significant at 5% probability level. ** : mean squares significant at 5% and 1% probability levels. respectively.
Table 3. Mean squares and mean value of yield and yield components and growth rates at 4 growth stages of 30 groundnuts improved cultivars released from 5 periods1.

| Characters                          | Mean squares | Mean value |
|-------------------------------------|--------------|------------|
| Plant height 15 dap                 | 0.234ns      | 6.52       |
| Plant height 30 dap                 | 7.343ns      | 12.24      |
| Plant height 60 dap                 | 22.970ns     | 31.69      |
| Plant height 80 dap                 | 25.610ns     | 41.23      |
| Number of branches 15 dap           | 0.642*       | 3.59       |
| Number of branches 30 dap           | 0.469ns      | 3.37       |
| Number of branches 60 dap           | 0.707ns      | 4.84       |
| Number of branches 80 dap           | 2.440ns      | 5.36       |
| No. of leaflet 15 dap               | 4.688**      | 9.23       |
| No. of leaflet 30 dap               | 14.720ns     | 21.00      |
| No. of leaflet 60 dap               | 109.300ns    | 64.22      |
| No. of leaflet 80 dap               | 271.300ns    | 78.97      |
| No. of gynophore 60 dap             | 174.900**    | 22.76      |
| No. of gynophore 80 dap             | 169.650**    | 17.93      |
| No. of young pods 60 dap            | 32.250ns     | 8.85       |
| No. of young pods 80 dap            | 23.240ns     | 10.34      |
| No. of filled pods 60 dap           | 29.730ns     | 14.44      |
| No. of filled pods 80 dap           | 62.160**     | 21.65      |
| Dry shoot weight 15 dap             | 4.440ns      | 4.70       |
| Dry shoot weight 30 dap             | 21.860ns     | 9.73       |
| Dry shoot weight 60 dap             | 477.600ns    | 68.47      |
| Dry shoot weight 80 dap             | 476.500ns    | 84.93      |
| Dry root weight 15 dap              | 0.117ns      | 0.81       |
| Dry root weight 30 dap              | 0.103ns      | 0.69       |
| Dry root weight 60 dap              | 12.710ns     | 14.42      |
| Dry root weight 80 dap              | 11.503ns     | 7.65       |
| Weight of young pods 60 dap         | 32.250**     | 8.40       |
| Weight of young pods 80 dap         | 23.240ns     | 10.65      |
| Weight of filled pods 60 dap        | 602.900ns    | 45.48      |
| Weight of filled pods 80 dap        | 480.300ns    | 59.96      |

1.1950-1980 (4 cultivars). 2. 1980-1990 (4 cultivars). 3. 1990-2000 (6 cultivars). 4. 2000-2010 (7 cultivars). and 5. >2010 (9 cultivars); ns : mean squares non-significant at 5% probability level *. ** : mean squares significant at 5% and 1% probability levels. respectively

3.2. Genetic gain for yield and yield components

Hypoma 1, Domba, and Bima, cultivars released after 2000’s produced pod yield significantly higher compared to those of the four oldest cultivars and even compared to the all released cultivars’pod yields (table 2). The significant increased indicating that there is yield improvement suggested genetic gene obtained over breeding of those three cultivars. Hypoma 1 and Bima developed from local cultivars, i.e. Local Lamongan, local Tuban, and local Bima (table 1), indicated the significant contribution of local
genetic resources in high yield of improved cultivars. There was an increase trend on pod yield and pod size during the release periods (table 4). Mean pod yield ranged from 1531.4 g 8m² for cultivars released in the 1980’s and 1847.7 g 8m², it means an increase of 316.3 g/8m² or 395.4 kg ha⁻¹ since 1950. Studies in several locations reported that yield gains were varied among locations (14; 15), suggested that the obtained yield gain rate confounded with location or environment.

| Era          | No. of cultivars | Plant height (cm) | No. of branches | Filled pods/plant | Weight of 100 pods (g) | 100 seed weight (g) | Pod yield (g/8m²) |
|--------------|------------------|-------------------|-----------------|-------------------|-----------------------|---------------------|------------------|
| 1950-1980    | 4                | 44.4              | 5.1             | 24.5              | 127.6                 | 52.2                | 1531.4           |
| 1981-1990    | 4                | 41.7              | 5.5             | 21.5              | 126.2                 | 49.0                | 1507.3           |
| 1991-2000    | 6                | 49.0              | 4.7             | 22.0              | 133.0                 | 44.1                | 1581.4           |
| 2001-2010    | 7                | 47.1              | 4.9             | 23.2              | 132.9                 | 43.6                | 1828.3           |
| >2010        | 9                | 42.0              | 6.4             | 22.9              | 130.7                 | 52.3                | 1847.7           |

Remarks: a1. 1950-1980 (4 cultivars). 2. 1980-1990 (4 cultivars). 3. 1990-2000 (6 cultivars). 4. 2000-2010 (7 cultivars). and 5. >2010 (9 cultivars)

Cultivars mean dry pod yield of the five classification eras ranged from 1531.4 g-1847.7 g/8m² (table 4), and regression of the 30 cultivars showed a yield gain of 5.89 kg/8m² or 0.38% year⁻¹ (figure 1). Similar result with higher yield gain obtained in Ethiopia, i.e. an annual relative genetic gain of 1.89% (16). No genetic gain on plant height and there were no correlations between plant height and pod yield (r= 0.12 ns). Significant progress has been made on pod size, an increase of 0.09 g year⁻¹ was recorded (figure 1). Relationship between pod size and pod yield was highly significant (r=0.315**) supporting the profile of those yield and pod size improvement. There was a negative gain or decreasing seed size and number filled pods during those breeding period (figure 2). Correlation analysis between the two characters, seed size and filled-pod number, showed weak correlations (r=0.12). The same picture was found on correlation between pod yield and the two characters, r=0.13ns and r=0.18ns for filled pod number and 100-seed weight respectively. This finding was not in line with others studies results (17, 18, 19, 20) which reported significant correlations between pod yield and those yield components. Even suggested that seed size and filled pod number as two characters among important yield attributes contribute to increasing groundnut pod yield (17). It is, therefore, suggested that breeding program to increase yield should give due attention to those yield-related traits. Employing large seeded and high yield potential groundnut germplasm would be prospective for improving groundnut cultivars. Addition biotic/abiotic tolerance characteristics in the newer improved cultivars did not decrease yield (table 3). This indicated that groundnut cultivars can be developed for many purposes without sacrificing the yield.
Figure 1. Relationship between pod yield of groundnut cultivars and year of breeding (left) and between pod size of groundnut cultivars and number year of breeding (right)

Figure 2. Relationship between seed size of groundnut cultivars and number year of breeding (left) and between filled pod per plant of groundnut cultivars and number year of breeding (right)

4. Conclusion
All the cultivars were highly varied in yield and yield components variables. However, there was no variability existence on the observed growth parameters except branch and leaflets number at 15 days and gynophore number at 80 days. Cultivars mean dry pod yield of the five classification eras ranged from 1531.4 g-1847.7 g 8m<sup>2</sup> with yield gain 6.9%. Significant progress has been made on pod size, yet seed size and filled pods number were decreasing. Therefore, it is suggested that breeding program is needed to increase yield should give due attention to those yield-related traits

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