Adaptive technology for soybean varieties cultivation in dry season

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Abstract. Rainfed lowland is a potential physical resource for soybean development to increase the cropping index. The study aimed to optimize the rainfed paddy fields by introducing a package which has several recommended technologies in a limited amount of water condition. The study was conducted in Sanca Village, Gantar District, Indramayu Regency from July to September 2019. The treatment was a recommended technologies package in soybean farming. The observed variables were plant height and number of branches in three growth phases, namely vegetative phase, flowering phase and maturing phase. The yield components were also observed. The collected data were analyzed by using t-test with technical cultivation of farmers' ways as a comparison. The results showed that the recommended technology package for soybean cultivation in the dry season produced higher soybean productivity (1.25 t ha\(^{-1}\)). Cultivation of soybeans in the dry season in rainfed lowland areas must pay attention to the suitability of varieties and availability of water sources in an effort to achieve optimal production.

1. Introduction
The area of rainfed paddy fields in West Java, Indonesia is 176,159 ha where 18,275 ha is in Indramayu Regency [1]. Developing this area has potential for increasing the cropping index. However, climate change limits the water availability due to less rainy days and depletion of groundwater reserves [2]. Crops cultivation in the rainfed area strongly depends on rainfall so the cropping pattern follows the season. However, due to climate change, the rain has stopped when the farmers are growing their second crops. Further, in the dry season, the rainy days become less due to climate change. These conditions limit the water supply, especially in the dry season. As the result, the farmers grow paddy once or twice a year, and then fallow [3]. To increase land productivity and cropping index, the fields cannot be fallow.

Rainfed lowland at dry season has potential for soybean cultivation. Some wetland paddy farmers in rainfed lowlands include soybean in their cropping pattern. Including soybean in cropping pattern is not only improving soil condition but also increasing income since soybean productivity that has grown after paddy is generally higher than grown in dryland [4]. However, several factors must be considered before including soybean in cropping patterns such as soybean harvesting time (< 80 days), land type, rainfall or water supply and season [5]. These factors are crucial for making a better growing condition for soybeans.

To maintain the optimal yield while adapting the short rainy season, the farmers need to grow early maturing soybeans [6]. Early maturing variety has a shorter vegetative phase than late-maturing variety. Because of the shorter vegetative phase, the soybean has entered the production phase when there is still
rain. Water is still available during the period from mid-pod elongation to just before seed enlargement which is a crucial time for achieving optimal growth and high productivity [7]. Thus, due to its characteristic, early maturing variety can adapt the climate change.

Some areas of rainfed paddy fields are usually in a higher place, so the existing irrigation system cannot reach them. As a result, in dry season these areas strongly dependent on rainwater and will not start a new planting season before the rain starts to fall regularly [5]. Therefore, cultivating soybean in these areas need to consider the water supply. Growing soybean in an area where water sources such as river or well are nearby can ensure the water availability by implementing an efficient irrigation/pumping or additional irrigation [8]. Thus, even though the rainwater is limited, it fulfils the water requirement for optimal growth.

Even though soybeans do not need water as much as paddy, they still need the right amount of water. The volume of water applied can be managed to increase the water use efficiency since the drought has an impact on decreasing soybean yield. At extraordinary drought condition, the yield decrease at more than 70% [9]. Watering half of the root area supports the growth, biomass, nodules, relative leaf water content, relative leaf chlorophyll content, leaf chlorophyll content and plant yields such as irrigation treatment of the entire root area and can increase leaf abscisic acid (ABA) content and water use efficiency [10]. Thus, in rainfed lowland where the water is limited in the dry season, the water regulation is needed.

The stress-induced by water deficits in plants depends on the conditions provided by the environment. It varies according to the intensity and duration of water deficits, the rate of water deficit induction and the stage of plant development when drought occurs [11]. To overcome the limited water in dry areas, farmers can build pump, reservoirs or water channels for irrigation [12]. Further, intermittent irrigation is also recommended to manage the available water. Intermittent irrigation is conducted by watering the plants according to plant critical phase, at least 2 times and a maximum of 5 times per week. Studies of plant irrigation techniques under controlled environmental conditions (greenhouses) showed that even though some of the roots are intermittently watered, soybean productivity was still high [8]. Thus, building water resources and intermittent irrigation minimize water stress by increasing the water availability and water use efficiency.

Applying technologies in soybean cultivation can make sure high productivity. Since every place has different environment condition, the applied technologies need to be site-specific. The application of site-specific technology is applied base on the potential of domestic resources by paying attention to environmental aspects. Thus, this study aimed to optimize rainfed paddy fields by introducing a recommended technologies package in a limited amount of water condition. The technology components in the package were land preparation, superior varieties, proper planting time management, good quality seeds, optimal plant population, and integrated pest control.

2. Materials and methods

2.1. Study area
A field study was conducted at Sanca Village, Gantar District, Indramayu Regency in June - August 2019. The plants were planted in plots of 0.5 ha.

2.2. Field experiment
The treatment was a recommended technologies package compare to farmers practices in soybean farming as detailed in Table 1. The package of recommended technology that has been used were: 1). Variety Dega-1, 2). Plant Spacing was jajar legowo 40 x 20 x 15 cm (forty to twenty to fifteen cm), 3). Rhizopus which mixed with the seed before planting at a dose of 2 g per kg of seed, 4). Compost organic fertilizer (1 t ha^-1), 5). Application of inorganic fertilizers such as Nitrogen, Phosphate and Potassium fertilizer at 7 to 10 Day After Sowing (DAS), 6). Irrigation for 2 (two) times a week and 7). Pesticide applications based on the Integrated Pest Management (IPM) concepts. Whereas, Farmers' methods were 1). Variety Anjasmor, 2). Plant spacing 30 x 30 cm (thirty to thirty cm), 3). Rhizoplus
which mixed before the seeds were to be planted at a dose of 2 g per kg of seed, 4). Non organic fertilizer 5). Anorganic fertilizer Urea and nitrogen, phosphate and potassium were applied at planting, 6). Irrigation for 3 times a week and 7). Pesticide was imposed every 1 (one) week (from planting to harvesting was sprayed for 12 times).

The river was pumped for irrigating the plants for 2 hours every 3 days in the field with technology package and every 2 days in the field with farmers’ method. The pump used a plastic hose with a diameter of 3 inches.

### Table 1. The package of recommended technologies and farmers' technologies at soybean cultivation in rainfed lowland in Indramayu Regency at second dry planting season 2019.

| No. | Treatment | Technology package | Farmers’ method |
|-----|-----------|-------------------|-----------------|
| 1.  | Variety   | Dega-1            | Anjasmoro       |
| 2.  | Planting space | Legowo (40 x 20 x 15) cm | 30 x 30 cm |
| 3.  | Rhizoplus | 2 g per kg seed | 2 g per kg seed |
| 4.  | Compost organic fertilizer (t ha⁻¹) | 1 | - |
| 5.  | An organic fertilizer | - Urea (kg ha⁻¹) | 50 | 100 |
|     |           | - NPK (kg ha⁻¹)  | 100            | 100 |
| 6.  | Irrigation interval per week (times) | 2 (watering 2 hours every three days) | 3 (watering 2 hours every two days) |
| 7.  | Pest and disease management | IPM concepts (pesticides were applied at economy threshold) | pesticides (12 applications) |

The observed variables were plant height, number of branches, flowering and ripening phase, number of pods, number of filled and unfilled pods per plant, the weight of 100 seeds and yield. The experiment used independent t-test was conducted (α=0.05) using SPSS V. 20.

### 3. Results and discussion

#### 3.1. Climate condition

There were very few rainy days and a low amount of rainfall and then stopped in April (table 1). Therefore, there was no rainfall during the study which lead to water deficiency. Soybeans respond differently to water deficiency at different growth stages. Generally, soybean has 5 critical phases, namely the germination phase (0 to 7) Day After Sowing, growth phase (25 to 35) Day After Sowing, flowering phase (45 to 55) Day After Sowing, pod filling phase (60 to 70) Day After Sowing and ripening phase (85 to 95) Day After Sowing. These critical phases depend on the variety and environmental conditions. The study of Karam et al. [13] reported that water deficiency during R3 (pod elongation) and R5 (grain enlargement) stage significantly reduces the yield. To minimize loss of yields at dry season, the farmers in New Delhi, India, add additional irrigation [14]. Thus, since there was water deficiency during the planting in this study, pumping the nearest river was conducted to obtain the water.

Soybean prefers dry climates to humid climates. The yields will be optimal if the precipitation is between 100 to 200 mm per month. Further, another study showed that 300 mm to 450 mm precipitation is the soybeans water need at 85 to 100 Day After Sowing [15]. Markovic et al. [16] reported that in the average growing season (2006 and 2008), adding water by keeping soil moisture content at 60 to 100% Field Water Capacity (FWC) was enough for water need of soybean, but a further increment of water ended with yield reduction by 2% (2006) and 6% (2008) as compared to deficit irrigated plots. This yield reduction at full irrigated plots may happen as a result of nutrient leaching in the soil, especially nitrates. Therefore, the field where technology package was implemented, irrigated the plant less than the field with farmers’ method since an 80 mm of irrigation water in the average climatic year is enough to compensate the lack of rainfall.
Table 2. Climate conditions in Sanca Village, Gantar District, Indramayu Regency, 2019.

| No. | Description                        | Months | Jan | Feb | March | April | May | June | July | August | Sept |
|-----|------------------------------------|--------|-----|-----|-------|-------|-----|------|------|--------|------|
| 1.  | Number of Precipitation (mm)       |        | 151 | 205 | 174   | 208   | -   | -    | -    | -      | -    |
| 2.  | Number of rainy days (days)        |        | 11  | 7   | 6     | 7     | -   | -    | -    | -      | -    |
| 3.  | Average of Precipitation (mm)      |        | 5   | 7   | 6     | 7     | -   | -    | -    | -      | -    |
| 4.  | Precipitation max (mm)             |        | 80  | 83  | 80    | 52    | -   | -    | -    | -      | -    |
| 5.  | Precipitation min (mm)             |        | 2   | 7   | 5     | 7     | -   | -    | -    | -      | -    |

Source: PSDA of Subang, West Java, Indonesia [17].

3.2. Soybean growth performances

The pest attack was relatively less. Although less, farmers sprayed the pesticide regularly every 6 days until 72 Day After Sowing. Differently, in the field of the recommended technologies package, the pesticide was only applied when the caterpillar attack occurred at 45 Day After Sowing. The strategy of IPM is to synergize all the technologies or methods to control pests and diseases based on the principles of ecology and economy. Therefore, the pesticide application is when the pest attack reaches the economic threshold. The used IPM principle in this study was 1). Cultivation of healthy plants, 2). Balancing environmental ecobiota components, 3). Preservation of natural enemies, 4). Integrated ecosystem monitoring, and 5). Increasing farmers awareness of pest and disease.

Dega-1 in the plot which applied the recommended technologies package had plant height and the number of branches higher than Anjasmoro in the vegetative, flowering and ripening stages (Table 2). Plant height affects the harvesting time and yield since the higher the plant, the vegetative phase will be longer which lead to a longer harvesting time. Thus, every late maturing variety of soybeans has a higher plant height [18]. Recommended technologies package has a positive effect on the growth of soybean especially the manure application which improves the soil and encourages a better growing environment for the plant. The manure implementation improves the physical, chemical and biological properties of the soil [19]. Further, organic fertilizers can hold the water in the soil by controlling the water infiltration rate [20]. Thus, adding the manure positively affects the growth and yield of soybeans.

Table 3. Growth of Dega-1 Variety (recommended technologies package) and Anjasmoro Variety (farmer’s method) at the second dry planting season in rainfed paddy fields in Indramayu Regency, 2019.

| Parameters                                      | Package of recommendation technologies | Farmers’ method | t value | CV (%) |
|------------------------------------------------|----------------------------------------|-----------------|---------|--------|
| Plant Height (cm)                               |                                        |                 |         |        |
| Vegetative phase                                | 35.52±3.41                            | 36.97±3.81      | *       | 0.86   |
| Flowering Phase                                 | 54.40±4.89                            | 50.25±3.25      | *       | 6.82   |
| Ripening Phase                                  | 39.20±5.70                            | 37.80±4.45      | *       | 4.67   |
| Number of Branches (branches)                   |                                        |                 |         |        |
| Vegetative phase                                | 1.50±1.00                             | 1.25±0.91       | *       | 0.36   |
| Flowering Phase                                 | 2.05±0.88                             | 1.85±1.13       | *       | 0.85   |
| Maturing Phase                                  | 2.10±1.16                             | 1.45±1.22       | *       | 0.52   |

Description: * = significantly different, tn = not significantly different.
3.3. Yield component
In the field with recommended technologies package, early maturing variety (i.e. Dega-1) had the number of pods, the number of filled pods, 100 grains weight and the yield of dry seeds higher than Anjasamoro (farmer method technology) (Table 3). These different yield components occurred not only due to the genetic potential but also the growing environment. The package of recommendation technologies provides a better environmental condition than the farmer’s cultivation method. Adding organic matter into the soil also improves the growing environment of soybean. Organic and inorganic fertilizers combination in the plot with the recommended technologies package had a positive effect on the yield. This combination significantly increased the yield component compared to using only inorganic fertilizers such as on the plot with farmers’ method. This positive result occurred because organic fertilizer can improve soil fertility and C-organic in the soil [21]. The result of this study is similar to the study of Abebe and Heile in 2017. Research result by Abebe et al. [20] showed that adding manure increases soybean yield at 84% because of manure supply nutrients throughout the season for the growth and development of soybean.

Agricultural management needs to adapt in response to climate change. Implementation of adaptation measures are the use of technology in agricultural land management, utilization of superior varieties that can adapt to climate change, management of planting time, water management technology and fertilization technology [22].

| Parameters                          | Technology                                      | t value | CV (%) |
|-------------------------------------|------------------------------------------------|---------|--------|
|                                     | Recommendation technology package               | Farmers’ method |       |        |
| Number of pods per plant            | 23.75±9.28                                     | 18.60±6.60 | *      | 10.30  |
| Number of filled pods per plant     | 14.85±4.60                                     | 12.75±4.71 | *      | 5.08   |
| Number of unfilled pods per plant   | 0.60±0.68                                      | 0.70±0.73  | tn     | 0.35   |
| Harvest time (DAS)                  | 70.00±0.00                                     | 80.00±0.00 | *      | 0.50   |
| Weight of 100 grains (g)            | 17.60±0.00                                     | 17.22±0.00 | *      | 0.38   |
| Dry seed yield (t ha⁻¹)             | 1.25±0.00                                      | 1.00±0.00  | *      | 0.10   |

Description: * = significantly different, tn = not significantly different.

In the dry season, soybean varieties play an important role in overcoming stress due to drought because the water need for each variety is different. Grobogan and Galunggung varieties are varieties that are resistant to drought stress and have low water requirements. At the earlier stage, these varieties need irrigation every 2 days, thus increasing their water requirements. However, at a late stage, their water requirement decreased to once every 4 days [15]. Decreasing water demand is one of the mechanisms for plants to become resistant to drought stress [23]. Further, early maturing soybean varieties have a shorter vegetative phase and a faster flowering time which lead to efficiency in water use [24]. This efficiency in water use offers benefits to farmers such as reducing the irrigation costs. Recommendation technology package by using the Dega-1 with a harvesting time at 70 Day After Sowing (DAS) only need additional irrigation by pumping at 2 times per week, while Anjasamoro needed additional irrigation at 3 times per week since it has a longer harvesting time (80 Day After Sowing). Thus, the plot with farmers’ method had a higher cost for water pumping. In facing climate change, early matured soybean varieties provide solutions for farmers, especially in preventing yield loss caused by drought and increasing the cropping index in a year [18].
The environmental conditions influence the number of soybean pods. Environmental conditions between the flowering and seed filling phase determine the number of seeds per unit area [25]. In this time, the plant needs regular irrigation to avoid water deficit. When the water deficit occurs, the flower and pod abortion increase [26].

Besides adding organic fertilizers, the planting distance also playing an important role in a higher yield of the plot with the recommendation technology package. Jajar legowo with the double row as a planting distance system, allowing the plants to have decent competition for light, water, and nutrition [27]. Jajar legowo makes it seem as if all the plants are on the edge thus allowed all plants to receive optimal sunlight. Planting soybeans with jajar legowo increase the yield by 17% compared to the single row [28]. Therefore, the plant in the plot with the recommended technologies package has a higher yield because the plants have a proper amount of light, water, and nutrition.

4. Conclusions
Recommended technologies package for soybean cultivation in the dry season using early maturing varieties, use of organic fertilizers, planting methods with legowo spacing and water management can produce high productivity of 1.25 t ha\(^{-1}\). Cultivation of soybeans in the dry season in rainfed lowland areas must pay attention to the suitability of varieties and availability of water sources in an effort to achieve optimal production.

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References
[1] BPS Provinsi Jawa Barat 2019 Jawa Barat Dalam Angka (in Bahasa) (Pemerintah Daerah Provinsi Jawa Barat)
[2] Hussain H A, Men S and Hussain S 2019 Interactive effects of drought and heat stresses on morpho-physiological attributes, yield, nutrient uptake and oxidative status in maize hybrids Scientific Reports 9 3890
[3] Ridwan and Zulrasdi 2010 PTT Kedelai Meningkatkan Pendapatan di Lahan Sawah Tadah Hujan (in Bahasa) (Balai Pengkajian Teknologi Pertanian Sumatera Barat)
[4] Syufri A 2012 Perbaikan Teknologi Budidaya Kedelai Tingkatkan Pendapatan Petani (in Bahasa) (Balai Pengkajian Teknologi Pertanian Sumatera Barat)
[5] Winardi 2014 Prospek Budidaya Kedelai Pada Lahan Sawah Tadah Hujan dan Sawah Irigasi Untuk Peningkatan Produksi Kedelai di Indonesia (in Bahasa) Agritech. 16 89 – 97
[6] Thamrin M, Ruchjaniningsih and Nappu M B 2013 Perubahan Iklim dan Antisipasi Teknologi dalam Pengelolaan Tanaman Jagung Lahan Kering Seminar Nasional Serelia (in Bahasa) (Makassar: Balai Pengkajian Teknologi Pertanian Sulawesi Selatan)
[7] Jonathan D, Haskett Yakov A, Pachepsky and Basil A 2000 Effect of climate and atmospheric change on soybean water stress: a study of Iowa Ecological Modelling 135 265-277
[8] Sutardi, Arlyna B P and Mulyadi 2014 Pengaruh frekuensi pengairan terhadap pertumbuhan dan hasil kedelai (in Bahasa) Jurnal Pengkajian dan Pengembangan Teknologi Pertanian 17 154-164
[9] Guoyong Leng G and Hall J 2018 Crop yield sensitivity of global major agricultural countries to droughts and the projected changes in the future Journal Science of the Total Environment 654 811-821
[10] Bahrun A, Rachmawati H, Muhidin and Dedi E 2012 Pengaruh Pengairan Separuh Daerah Akar terhadap Efisiensi Penggunaan Air dan Produksi Kedelai (Glycine max L.) pada Musim Kemarau (in Bahasa) Jurnal Agronomi Indonesia 40 36-41
[11] Bertolli S C , Rapchan G L and Souza G M 2012 Photosynthetic limitations caused by different rates of water-deficit induction in Glycine max and Vignaunguiculata Photosynthetica 50 329-336 doi: 10.1007/s11099-012-0036-4
[12] Chartzoulakisa K and Bertaki M 2015 Sustainable water management in agriculture under climate change Agriculture and Agricultural Science Procedia 4 88-98
[13] Karam F, Masaad R, Sfeir T, Mounzer O and Rouphael Y 2005 Evapotranspiration and grain yield of field grown soybean under deficit irrigation conditions Agricultural Water Management 75 225-244
[14] Prakash K J, Soora N K and Amor V M I 2018 Responses of soybean to water stress and supplemental irrigation in upper Indio-Gangetic plain: Field experiment and modeling approach Journal of Field Crops Research pp 76-86 journal homepage: www.elsevier.com/locate/fcr.
[15] Suryanti S, Indradewa D, Sudira P and Widada J 2015 Kebutuhan Air, Efisiensi, Penggunaan air dan ketahanan kekeringan Kultivar Kedelai (in Bahasa) Agritech. 35 114-140
[16] Markovic M, Josipovic M, Ravlić M, Josipovic A and Zebec V 2016 Deficit Irrigation of soybean (Glicine max (L.) Merr) based on monitoring of soil moisture, in sub-humid area of Eastern Croatian Agricultural Research 33 1-8
[17] PSDA Kabupaten Subang 2019 Pengelolaan Sumberdaya Air (in Bahasa) (Subang: Dinas Bina Marga dan Pengairan Kabupaten Subang)
[18] Rahajeng W and Adie M M 2013 Varietas Kedelai Umur Genjah Buletin Palawija 26 91-100
[19] Bandyopadhyay K K , Misra A K , Ghosh P K and Hati K M 2010 Effect of integrated use of farmyard manure and chemical fertilizers on soil physical properties and productivity of soybean Soil and Tillage Research 110 115 - 125 https://doi.org/10.1016/j.still.2010.07.007
[20] Abebe Z A and Haile D 2017 The effect of organic and inorganic fertilizers on the yield of two contrasting soybean varieties and residual nutrient effects on a subsequent finger millet crop Journal Agronomy 7 1-15 doi:10.3390/agronomy7020042
[21] Yamika W S D and I K R Ikawati 2012 Combination inorganic and organic fertilizer increased yield production of soybean in rain-field Malang, Indonesia American-Eurasian Journal of Sustainable Agriculture 6 14-17
[22] Thamrin M, Ruchjaniingsih and Nappu M B 2013 Perubahan Iklim dan Antisipasi Teknologi dalam Pengelolaan Tanaman Jagung Lahan Kerin (in Bahasa) Seminar Nasional Serelia Balai Pengkajian Teknologi Pertanian Sulawesi Selatan, Makassar pp 353-370
[23] Zhou Y Christopher, J Lambrides, Kearns, R Ye C and Fukai S 2012 Water use, water use efficiency and drought resistance among warm-season turfgrasses in shallow soil profiles Functional Plant Biology 39 116-125. https://doi.org/10.1071/FP11244
[24] Arajia H A, Wayayoka A, Bavanic A M, Amirid E, Abdullaha A F, Daneshiane J and Teh C B S 2018 Impacts of climate change on soybean production under different treatments of field experiments considering the uncertainty of general circulation models Journal Agricultural Water Management 205 63 - 71 https://doi.org/10.1016/j.agwat.2018.04.023
[25] Chartzoulakisa K and Bertaki M 2015 Sustainable water management in agriculture under climate change Agriculture and Agricultural Science Procedia 4 88-98
[26] Comlekcioglu N and Simsek M 2011 Effect of deficit irrigation on yileld and yield components of vegetable soybean [Glycine max L. (merr.)] in semi-arid condition African Journal of Biotechnology 10 6227-6234
[27] Sundari T and Pratiwi H 2018 Effects of Planting Pattern on The Performance of Soybean Genotypes Planta Tropika Journal of Agro Science 6 39-48
[28] Grichar W J 2007 Row spacing, plant populations and cultivar effects on soybean production along Texas Gulf Coast Crop Manag. doi: 10.1094/CMA-2007-0615-01-RS