Effect of integrated technologies on the productivity of maize, sorghum and pearl millet crops for improving resilience capacity to climate change effects in the dry lands of Eastern Amhara, Ethiopia

Amare Aleminew, Tilahun Tadesse, Yeshitla Merene, Wondimu Bayu and Yigzaw Dessalegn

Abstract: Three sets of field experiments were conducted both on farmer fields and on experiment stations on Kobo areas of eastern Amhara region during 2013 and 2014 cropping seasons to evaluate and introduce dry land crop production technologies that would reduce crop failure and increase productivity of crops. Integrated technologies that were evaluated include: micro-dose fertilizer, moisture conservation, seed priming, intercropping, and row planting. The experimental design was randomized complete block (RCB) with three replications consisted of 14 treatments. The results revealed that the highest grain yield (5032 and 4328 kg/ha) of sorghum was recorded with application of recommended fertilizer rate + primed seed + tied ridge and micro-dose fertilizer + primed seed + tied ridge + intercropping with haricot bean, respectively. For pearl millet, the highest grain yield (3355 and 3355 kg/ha) was recorded with recommended fertilizer rate + dry seed + tied ridge and mung bean + micro-dose fertilizer + primed seed + tied ridge + intercropping with mung bean, respectively.

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PUBLIC INTEREST STATEMENT

Maize, sorghum, and pearl millet have the potential food security crop for 1,00,000 people in dry lands of eastern Amhara region of Ethiopia. Applications of efficient integrated technologies for climate change resilience are not common in the dry lands of Amhara region. However, food insecurity due to low crop productivity results in malnutrition in the area is the major ones. Here, we compared micro-dose fertilizer, moisture conservation, seed priming, intercropping, and row planting to improve the productivity of different crops. However, applications of recommended fertilizer rate + primed seed + tied ridge for sorghum testing crop, recommended fertilizer rate + dry seed + tied ridge for pearl millet and micro-dose fertilizer + primed seed + tied ridge + intercropping with mung bean for maize was recommended and intensified on a large scale in present and future for Kobo and similar areas based on the results of on-station and on-farm trials.
3145 kg/ha) was recorded with application of micro-dose fertilizer + dry seed + tied ridge and recommended fertilizer rate + dry seed + tied ridge, respectively. For maize, the highest grain yield (4414 and 4392 kg/ha) was recorded with application of micro-dose fertilizer + primed seed + tied ridge + intercropping mung bean and recommended fertilizer rate + dry seed + tied ridge. From the results of on-station and on-farm trials at Kobo, recommended fertilizer rate + primed seed + tied-ridge for sorghum testing crop, recommended fertilizer rate + dry seed + tied-ridge for pearl millet and micro-dose fertilizer + primed seed + tied ridge + intercropping with mung bean for maize was recommended for kobo and similar areas.

Subjects: Agriculture & Environmental Sciences; Soil Sciences; Environmental Management; Environment & Resources;

Keywords: food security crops; integrated technologies; micro-dose fertilizer; seed priming

1. Introduction

Sorghum, pearl millet, and maize are the potential food security crops in dry land areas (Central Statistical Agency [CSA], 2019; Chisi & Peterson, 2019). Food insecurity is the major problem in most of the dry land areas of eastern Amhara region. The low productivity of farmlands in the dry lands is partly attributed to low soil fertility, drought, and frequent pest and disease outbreak (Firdaus, Gunaratne, Rahmat, & Kamsi, 2019; Nyamangara, Kodzwa, Masvaya, & Soropa, 2020). High population growth rate and deep rooted poverty exacerbated the problem of food insecurity in the area. Governmental as well as non-governmental organizations also introduced and demonstrated improved agricultural technologies to farmers in the area (Wondimu et al., 2010). However, their effort was not successful as expected and could be attributed to several reasons. One of the reasons was fertilizer applications in dry land area is very difficult due to moisture deficiency, even the applied fertilizer is not properly taken by crops. Therefore, sustainable crop productivity subsequently food security can only be achieved if agricultural production problems are solved following integrated approach (Kidane, Alemneh, & Meshack, 2010; Pretty, Toulmin, & Williams, 2011). Climate change results in food insecurity and it affects the food availability, accessibility, food utilization, and the stability of food systems (Firdaus et al., 2019). Seed priming, tie-ridging, intercropping, micro-dose fertilizer applications, and mulching are some of the effective technologies to alleviate the effect of moisture stress in dry land areas (Clark et al., 2002; Ram, Peter, Kanwar, & Suhas, 2012; Sanou et al., 2016).

Major factors that limit crop productivity in Sub-Saharan Africa are erratic rainfall and depletion of soil fertility (Agyin-Birikorang et al., 2019; Nyamangara et al., 2020). These long-term changes could be an evidence for climate change are expected to shift production seasons, pests, and diseases, modify the set of feasible crops and its productivity. These problems are very serious in dry land areas of many countries (Melese, 2019). Adapting to climate change resilient practices to alleviate the major problems encountered in dry land crops productivity are seed priming, micro-dose fertilizer applications, intercropping with grain legumes, moisture conservation techniques like tie-ridging, mulching, and crop variety selection (Agyin-Birikorang et al., 2019; Clark et al., 2002; Melese, 2019; Ram et al., 2012; Sanou et al., 2016; Shapiro-Garza, King, Rivera-Aguirre, Wang, & Finley-Lezcano, 2019; Wondimu et al., 2010). These technologies should be applied in an integrated manner to attain agronomically feasible, environmentally sound and economically viable and sustainable productivity of crops. On the one hand, climate change effects were mitigated and adapted through the use of biotechnological approaches in biotic and abiotic stresses (Wakjira, 2018). To enhance the productivity of dryland crops, use of modern and climate sensitive technologies like synthetic fertilizers are crucial in an integrated manner (Nyamangara et al., 2020).

There is a long-standing conception by farmers that many of the improved technologies are developed for wet areas and some technologies like fertilizers are totally irrelevant to their areas.
However, in the long run, the experiment brought change in attitude of dry land farmers towards improved technologies, through learning by doing (Kidane, Melesse, & Shilima, 2002; Pretty et al., 2011). A study in Uganda response of maize to nitrogen fertilization methods would increase maize yield by 104% compared to check plots (Oyebiyi et al., 2019). Fertilizer application in the developing world commonly achieved by broadcasting without proper placement leads to volatilization and leaching of nutrients (Li, Kong, Wu, Feng, & Jichao, 2019; Oyebiyi et al., 2019) without uptake by crops. This results in reduction of fertilizer use efficiency of crops. Among fertilizer application methods in dryland areas, micro-dose fertilizer application is beneficial due to its efficiency, easily taken by crops since, it was applied near to the roots of plants, and its application rate is too low and it can reduce the fertilizer transaction costs as compared to conventional recommended rates for crops (Ram et al., 2012; Sanou et al., 2016).

Currently, there is a new technique to manage the required nutrients for crops, there is stable intra-field heterogeneity maps based on big satellite data analysis can be used to intensify the agricultural systems of crops (Khitrov et al., 2019). With increasing doses of ammonium nitrate from 50 to 350 kg ha$^{-1}$, wheat yield is increased by 26% in the low fertility zone, 50% in the normal fertility zone, and 70% in the high fertility zone by using big satellite data heterogeneity maps for nitrogen fertilizer responsiveness (Khitrov et al., 2019). Applications of improved integrated technologies are the best smart-climate agriculture options to cope with climate change effects on crops in dry lands (Sanou et al., 2016). This is the most important pillar for increasing the efficiency of nitrogen fertilizers for raising the production of crops without increasing the cost of production. There is paucity of information regarding to the applications of dry lands integrated technologies for enhancing the productivity of crops and resilience or escaping the effects of climate change on crops productivity in eastern Amhara region of Ethiopia. Therefore, this study is meant to evaluate, identify, and introduce location-specific dry land crop production technologies that would reduce crop failure and increase productivity in dry lands of Amhara region.

2. Materials and methods

Three sets of experiments were conducted both on farmer fields and on experiment stations at one district of Eastern Amhara region, namely Kobo for two consecutive years (2013–2014). At on-station, the experiment consists of sorghum, pearl millet, and maize where as for the on-farm experiments pearl millet and sorghum at Kobo on two Kebeles, namely Abuare and Aradom, was used based on the results of 2013 from on-station experiments. Then from the 14 treatments, six best-performed treatments were selected and done in 2014 at two Kebeles of farmers’ field. Technologies that were evaluated include: fertilizer micro-dosing, moisture conservation, seed priming, intercropping, and row planting. The 14 treatments were (1) No fertilizer + dry seed + flatbed, (2) No fertilizer + dry seed + Tied ridge, (3) No fertilizer + primed seed + flatbed, (4) No fertilizer + primed seed + tied ridge, (5) Recommended fertilizer rate + dry seed + flatbed, (6) Recommended fertilizer rate + dry seed + tied ridge, (7) Recommended fertilizer rate + primed seed + flatbed, (8) Recommended fertilizer rate + primed seed + tied ridge, (9) Micro-dose + dry seed + flatbed, (10) Micro-dose + dry seed + tied ridge, (11) Micro-dose + primed seed + flatbed, (12) Micro-dose + primed seed + tied ridge, (13) Micro-dose + primed seed + tied ridge + intercropping (mung bean), and (14) Micro-dose + primed seed + tied ridge + intercropping (haricot bean).

The recommended fertilizer rates were 100 kg DAP and 50 kg urea/ha, DAP applied at planting and urea applied at knee height stage. Fertilizer micro-dosing was done at 0.5 g DAP/pocket at planting and 0.5 g urea/pocket at knee height stage. Seed priming was done by soaking sorghum and pearl millet seeds in water for 8 hours and maize seeds for 14 hours and dried before planting. In the case of intercropping, maize, sorghum, and pearl millet were planted in the furrows and mung bean and haricot bean were planted on the ridges. Mung bean and haricot bean were planted on additive basis after every two rows of the main crop.
The experimental design was randomized complete block (RCB) with three replications. The gross plot size was $4.5 \times 5 \text{ m} = 22.5 \text{ m}^2$ with the net plot size of $3 \times 4 \text{ m} = 12 \text{ m}^2$. Spacing between adjacent replications and plots was 1.5 m and 0.5 m, respectively. Planting for sorghum and pearl millet was made at the spacing of 75 cm between rows and 15 cm between plants. Maize was planted at the spacing of 75 cm between rows and 25 cm between plants. Tied-ridges were constructed before planting. Tieing the ridge was done as needed for each site.

Data collection and analysis: For the on-station experiments initial soil sample at the soil depth of 0–20 cm from five points from the whole experimental field was collected where composite sample was made and analyzed for physicochemical properties of the soil (texture, OM, N, P, K, CEC, pH). Agronomic data were collected with respective measures. Mean value of physico-chemical soil properties at Kobo on-station and rain fall amount in 2013 and 2014 were illustrated, respectively in Table 1 and Figure 1. The collected data were analyzed by using statistical analysis system (SAS) software with a version of 9.2 (SAS-Institute, 2008).

3. Results and discussion
Parameters such as days to maturity, plant height, head weight, biomass yield, and grain yield of pearl millet showed significant differences, but other parameters did not show significant differences (Table 2). The highest grain yield (2839.8 kg/ha) of pearl millet was recorded at no fertilizer + dry seed + tie ridge treatment (Table 2). Parameters such as days to emergence and biomass

Table 1. Mean value of some parameters of soil samples taken before planting at Kobo on-station

| Site               | pH  | %OM | %N  | P   | K meq/100 | CEC meq/100 | %clay | %silt | %sand |
|--------------------|-----|-----|-----|-----|-----------|-------------|-------|-------|-------|
| Kobo on-station    | 6.25| 1.58| 0.15| 12  | 0.33      | 25.64       | 27.5  | 57.5  | 15    |

Status: SA = slightly acidic; M = medium and H = high

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![Rain fall distribution and amount (mm) at Kobo in cropping seasons of 2013 and 2014.](image-url)
| Treatments            | DE  | DH  | DM   | PH   | NTPP | HL   | HWt  | NHPP | BY    | TKW  | GY   |
|-----------------------|-----|-----|------|------|------|------|------|------|-------|------|------|
| NF + DS + FB          | 6   | 51.7| 82a-e| 163.7cd| 3.3  | 18.7 | 4333.3ef | 240  | 9467de | 9.8  | 1789.6def |
| NF + DS + TR          | 6   | 52.7| 84a  | 168.7b-d| 4    | 18.3 | 6133.3a  | 275  | 15200a | 9.3  | 2839.8a |
| NF + PS + FB          | 6   | 49.7| 79.3f| 158d | 3.3  | 18.7 | 3733.3f  | 228.3| 8933de | 7.5  | 1171.3f |
| NF + PS + TR          | 6   | 52.3| 83.7ab| 178.7ab| 3.3  | 19.7 | 5466.7a-d | 220.3| 12800a-d | 8.7  | 2349.3a-d |
| RFR + DS + FB         | 6   | 51.7| 81.3c-f| 162.3cd| 4.3  | 20   | 5200a-e  | 263.3| 10600c-e | 9.4  | 2088.4b-e |
| RFR + DS + TR         | 6   | 52.3| 83.7ab| 188a | 4.3  | 19.7 | 6000a  | 239.7 | 14133a-c | 9.2  | 2537.6a-c |
| RFR + PS + FB         | 6   | 51.6| 81.7b-e| 160.7cd| 3.3  | 20   | 4400d-f  | 213.7 | 9867de  | 9.8  | 1998.7c-e |
| RFR + PS + TR         | 6   | 53  | 83a-c| 174bc | 3.7  | 20   | 4866.7b-e | 221.3| 11200b-e | 8.6  | 1875.8c-e |
| MD + DS + FB          | 6   | 50.3| 80.7d-f| 167.7b-d| 3.7  | 20   | 4866.7b-e | 241.7| 10333c-e | 7.7  | 1825.8d-f |
| MD + DS + TR          | 6   | 52.7| 84a  | 173.3bc | 4    | 20.7 | 5933.3ab | 250  | 14667ab | 9.4  | 2714ab |
| MD + PS + FB          | 6   | 50.3| 80ef | 164cd | 3.3  | 19   | 4666.7c-f | 220  | 8000e  | 6.9  | 1423.3ef |
| MD + PS + TR          | 6   | 52  | 82.7a-d| 168.3b-d| 3.3  | 20.3 | 5066.7a-e | 235.7| 12867a-d | 9.4  | 2258.9a-d |
| MD + PS + TR + MB     | 6   | 53  | 83.7ab| 174bc | 3.7  | 22   | 5700 o-c | 263.3 | 12400a-d | 9    | 2535.8a-c |
| MD + PS + TR + HB     | 6   | 51  | 82.7a-d| 174bc | 3.7  | 20   | 4200ef  | 208.7 | 9067de  | 8    | 1829.1d-f |
| LSD0.05               | ns  | ns  | 2.16 | 13.78 | ns  | ns  | 1119.1 | ns  | 3939.3 | ns  | 678.88 |
| CV (%)                | -   | 2.4 | 1.6  | 4.8  | 22.4 | 7.1  | 13.2  | 13.2  | 20.6  | 17.1 | 19.4 |

ns = non-significant; DE = days to emergence; DH = days to heading; DM = days to maturity; PH = plant height (cm); NTP = number of tillers per plant; HL = head length; HWt = head weight; NHPP = number of heads per plot; BY = biomass yield (kg ha\(^{-1}\)); TKW = thousand kernels weight (g); GY = grain yield (kg ha\(^{-1}\)); NF = no fertilizer; DS = dry seed; FB = flatbed; TR = tie ridge; RFR = recommended fertilizer rate; PS = primed seed; MD = micro-dose; IBM = intercropped mung bean; IHB = intercropped haricot bean
| Treatments          | DE     | DH    | DM    | PH    | NTPP  | HL    | HWt   | NHPP  | BY    | TKW   | GY    |
|---------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| NF + DS + FB        | 6.3d-f | 52.0b-d | 93.7  | 175.0b-e | 4.7   | 21.0  | 7933  | 255.7 | 18222b-e | 14.3 | 3647a-c |
| NF + DS + TR        | 5.0f   | 52.0b-d | 98.3  | 170.3c-e | 3.7   | 18.0  | 4533  | 242.0 | 14667ef | 15.3 | 2733c   |
| NF + PS + FB        | 6.3d-f | 52.0b-d | 96.7  | 170.7c-e | 3.7   | 18.3  | 5933  | 250.3 | 1644c-f | 17.0 | 3375a-c |
| NF + PS + TR        | 8.3ab  | 55.3a  | 96.3  | 164.3de | 4.7   | 19.3  | 5267  | 185.7 | 12000f  | 15.0 | 2818c   |
| RFR + DS + FB       | 5.3ef  | 50.0d  | 93.0  | 156.7e  | 3.0   | 20.7  | 8600  | 316.0 | 24222a  | 14.7 | 4064ab  |
| RFR + DS + TR       | 5.3ef  | 52.7a-d | 94.3  | 184.0a-c | 3.7   | 20.0  | 7000  | 254.0 | 20889a-d | 14.7 | 3753a-c |
| RFR + PS + FB       | 6.3c-f | 51.0cd | 92.3  | 179.0a-d | 3.7   | 21.3  | 7867  | 290.7 | 21333a-c | 15.3 | 3004bc  |
| RFR + PS + TR       | 6.7c-f | 52.3a-d | 96.3  | 175.7b-e | 4.7   | 18.3  | 5867  | 164.7 | 15333ef | 18.0 | 3066a-c |
| MD + DS + FB        | 7.0b-e | 54.3ab | 96.0  | 193.0ab | 4.7   | 21.3  | 8267  | 244.3 | 22000ab | 16.3 | 4160a   |
| MD + DS + TR        | 6.3c-f | 53.3a-c | 93.7  | 195.3a  | 4.0   | 19.7  | 7267  | 231.3 | 21333a-c | 14.7 | 3996ab  |
| MD + PS + FB        | 8.7a   | 53.7a-c | 95.0  | 182.3-d | 4.7   | 19.3  | 7467  | 277.3 | 18444b-e | 18.0 | 4200a   |
| MD + PS + TR        | 8.0a-c | 54.7ab | 98.0  | 172.0c-e | 5.7   | 19.0  | 5467  | 176.7 | 15111ef | 16.0 | 2821c   |
| MD + PS + TR + IMB   | 7.7a-d | 55.0ab | 99.0  | 187.7a-c | 5.0   | 22.7  | 5400  | 187.0 | 13778ef | 15.3 | 2937bc  |
| MD + PS + TR + IHB   | 7.7a-d | 52.0b-d | 97.0  | 184.3a-c | 5.7   | 20.3  | 5200  | 262.0 | 15778d-f | 17.0 | 2786c   |
| LSD0.05             | 1.5    | 2.7   | ns    | 16.2   | ns    | ns    | ns    | ns    | 4794.6 | ns    | 1005.2  |
| CV (%)              | 12.8   | 3.1   | 2.8   | 5.7    | 30.8  | 12.3  | 24.9  | 29.6  | 160.0  | 13.0  | 17.7    |

ns = non-significant; DE = days to emergence; DH = days to heading; DM = days to maturity; PH = plant height (cm); NTP = number of tillers per plant; HL = head length; HWt = head weight; NHPP = number of heads per plot; BY = biomass yield (kg ha⁻¹); TKW = thousand kernels weight (g); GY = grain yield (kg ha⁻¹); NF = no fertilizer; DS = dry seed; FB = flatbed; TR = tie ridge; RFR = recommended fertilizer rate; PS = primed seed; MD = micro-dose; IMB = intercropped mung bean; IHB = intercropped haricot bean
yield of pearl millet showed very highly significant differences, but plant height showed highly significant while grain yield and days to heading were showed significant (Table 3). The highest grain yield (4200 and 4160 kg/ha) of pearl millet was recorded at micro-dose fertilizer + primed seed + flat bed and micro-dose fertilizer + dry seed + flat bed, respectively at Kobo on-station (Table 3). Parameters such as days to emergence, number of cobs per plant and grain yield of maize showed significant differences (Table 4). The highest grain yield (5653 and 5449 kg/ha) of maize was recorded at recommended fertilizer rate + dry seed + tied ridge and micro-dose fertilizer + primed seed + tied ridge + intercropping with mung bean, respectively at Kobo on-station in 2014 (Table 4). Additionally, intercropping of mung been to maize gave 230 kg/ha at Kobo on-station in 2014 (Table 4). For on-farm trials at Kobo, all parameters of pearl millet showed non-significant (Table 5) while biomass yield of sorghum showed highly significant and head weight and grain yield showed significant in 2014 (Table 6). The highest grain yield (2273 kg/ha) of pearl millet was recorded with application of recommended fertilizer rate + dry seed + tied ridge (Table 5). The highest grain yield (5032 kg/ha) of sorghum was recorded with application of recommended fertilizer rate + primed seed + tied ridge (Table 6).

Mean combined analysis over two years (2013 and 2014) integrated application of dry land technologies were showed very highly significant differences between days to emergence and plant height and highly significant difference between days to heading, days to maturity and significant difference between biomass yield of pearl millet at Kobo on-station (Table 7). The highest grain yield (3355 kg/ha) was recorded with application of micro-dose fertilizer + dry seed + tied ridge (Table 7). Similarly, mean combined analysis over two years (2013 and 2014) integrated application of dry land technologies were showed significant differences between days to emergence of maize at Kobo on-station (Table 8). The highest grain yield (4414 kg/ha) was recorded with application of micro-dose fertilizer + primed seed + tied ridge + intercropping mung bean (Table 8). Intercropping mung bean with maize gave additional 230 kg/ha yields.

It is beneficial to combine seed priming with micro-dose fertilizer application as the best effect of mineral fertilizer was observed when priming was undertaken. Generally, from these experiments, integrated application of technologies like seed priming, tied-ridging, micro-dosing and recommended fertilizer applications, and row planting and intercropping of legumes with cereal crops such as maize, sorghum, and pearl millet would increase crop yields in dry land areas of Kobo. Therefore, these results would be similar to works of Melesse, Kidane, Shilima, and Hirut (2002), Ramadjita et al. (2008), Aune and Ousman (2011), Ram et al. (2012), Camara, Camara, Berthe, and Oswald (2013) and Getachew and Jens (2014). Although there have been many research activities which demonstrate that the integrated approach, i.e., combining improved varieties with agronomic practices, improve crop productivity (Kidane, 2003). Moreover, application of integrated technologies would have the ability to reduce the effects of climate change effects on crops productivity by resilience strategies or escaping the damage effects on crops (Pretty et al., 2011; Sanou et al., 2016; Shapiro-Garza et al., 2019).

4. Conclusions
Application of integrated dry land technologies would have the capacity to improve resilience to climate change effects on crop yields in the dry areas. Seed priming technology is advantageous for sorghum and maize, but it is disadvantageous for pearl millet production at Kobo areas. On the other hand, tied ridge increases yield of crops than flat-bed making because of conserving soil moisture content. From the results of on-station and on-farm trials at Kobo, recommended fertilizer rate + primed seed + tied-ridge for sorghum testing crop, recommended fertilizer rate + dry seed + tied-ridge for pearl millet and micro-dose fertilizer + primed seed + tied ridge + intercropping with mung bean for maize was recommended for Kobo and similar areas. Since, micro-dosing fertilizer application enhances fertilizer use efficiency and reduces the total amount of fertilizer required, as option it will be secondary recommendation for sorghum and pearl millet crops for Kobo and similar areas.
Table 4. Effect of integrated technologies on productivity of maize at Kobo on-station in 2014

| Treatments            | Parameters | DE  | DT | DM  | PH  | CL  | NCPP | BY  | TKW | GY   |
|-----------------------|------------|-----|----|-----|-----|-----|------|-----|-----|------|
| NF + DS + FB          |            | 7.0ab | 67.7 | 116.3 | 176.7 | 20.0 | 41.0de | 11111 | 301.7 | 2921b |
| NF + DS + TR          |            | 7.3a  | 68.0 | 112.3 | 178.3 | 19.0 | 38.7e | 10667 | 293.7 | 2709b |
| NF + PS + FB          |            | 5.0bc | 64.3 | 116.3 | 174.7 | 20.7 | 46.0c-e | 11778 | 316.3 | 2655b |
| NF + PS + TR          |            | 4.7c  | 61.0 | 111.3 | 183.7 | 21.3 | 53.3a-e | 13556 | 312.8 | 3742ab |
| RFR + DS + FB         |            | 6.3a-c| 64.3 | 113.7 | 184.0 | 22.7 | 48.7b-e | 13111 | 288.7 | 4086ab |
| RFR + DS + TR         |            | 6.3a-c| 65.0 | 112.3 | 201.7 | 22.0 | 69.7a  | 18222 | 330.7 | 5653a |
| RFR + PS + FB         |            | 6.0a-c| 66.3 | 111.3 | 190.7 | 20.0 | 49.3b-e | 14444 | 326.0 | 4371ab |
| RFR + PS + TR         |            | 4.7c  | 67.3 | 111.7 | 199.0 | 20.7 | 55.7a-e | 15111 | 303.0 | 4313ab |
| MD + DS + FB          |            | 7.7a  | 67.7 | 112.3 | 185.0 | 19.7 | 48.7b-e | 14000 | 319.0 | 4120ab |
| MD + DS + TR          |            | 7.7a  | 67.0 | 113.7 | 198.7 | 21.0 | 55.3a-e | 15333 | 321.3 | 4072ab |
| MD + PS + FB          |            | 6.7a-c| 68.0 | 112.7 | 184.0 | 22.0 | 59.0a-d | 15111 | 318.7 | 4510ab |
| MD + PS + TR          |            | 6.7a-c| 66.7 | 112.0 | 187.3 | 21.3 | 63.0a-c | 13556 | 312.0 | 4356ab |
| MD + PS + TR + IMB    |            | 5.7a-c| 62.3 | 111.0 | 198.7 | 22.3 | 68.0ab | 16444 | 353.0 | 5449a |
| MD + PS + TR + IHB    |            | 5.7a-c| 68.7 | 114.3 | 187.3 | 21.7 | 39.3de | 16444 | 329.3 | 4375ab |
| LSED<sub>0.05</sub>  |            | 1.8   | ns  | ns  | ns  | ns  | 17.0 | ns  | ns  | 1741.0 |
| CV (%)                |            | 8.9   | 6.7 | 2.9 | 6.2 | 9.5 | 19.3 | 19.0 | 7.3 | 25.3 |

ns = non-significant; DE = days to emergence; DT = days to tasseling; DM = days to maturity; PH = plant height (cm); CL = cob length (cm); NCPP = number of cobs per plot; BY = biomass yield (kg ha<sup>-1</sup>); TKW = thousand kernels weight (g); GY = grain yield (kg ha<sup>-1</sup>); NF = no fertilizer; DS = dry seed; FB = flatbed; TR = tie ridge; RFR = recommended fertilizer rate; PS = primed seed; MD = micro-dose; IMB = intercropped mung bean; IHB = intercropped haricot bean
### Table 5. Effect of integrated technologies on productivity of pearl millet at Kobo on-farm in 2014

| Parameters | Treatments     | DE  | DH  | DM  | PH  | NTPP | HL  | HWt | NHPP | BY  | TKW  | GY  |
|------------|----------------|-----|-----|-----|-----|------|-----|-----|------|-----|------|-----|
|            | NF + DS + TR   | 6.5 | 51.0| 97.5| 166.5| 2.5  | 16.5| 4900| 230.0| 10,733| 14.5 | 1852 |
|            | RFR+DS+TR      | 5.0 | 51.0| 98.0| 186.5| 1.5  | 16.5| 5000| 200.0| 14,067| 15.0 | 2273 |
|            | RFR+PS+TR      | 6.5 | 52.5| 99.0| 185.5| 2.5  | 17.5| 5200| 245.0| 16,000| 15.5 | 1698 |
|            | MD+DS+TR       | 6.5 | 51.5| 99.0| 182.5| 2.5  | 19.0| 5100| 172.5| 11,600| 16.5 | 2018 |
|            | MD+PS+TR       | 5.5 | 52.0| 98.5| 174.0| 3.0  | 19.5| 5300| 191.0| 13,000| 19.5 | 2112 |
|            | MD+PS+TR+IBM   | 6.0 | 52.5| 99.0| 172.0| 3.5  | 18.5| 3400| 108.0| 10,000| 16.0 | 1575 |
|            | LSD0.05        | ns  | ns  | ns  | ns  | ns   | ns  | ns  | ns   | ns  | ns   | ns  |
|            | CV %           | 23.2| 3.6 | 1.7 | 9.9 | 33.5 | 14.2| 10.4| 22.2 | 22.6| 15.8 | 26.9|

*ns = non-significant; DE = days to emergence; DH = days to heading; DM = days to maturity; PH = plant height (cm); NTP = number of tillers per plant; HL = head length; HWt = head weight; NHPP = number of heads per plot; BY = biomass yield (kg ha⁻¹); TKW = thousand kernels weight (g); GY = grain yield (kg ha⁻¹); NF = no fertilizer; DS = dry seed; FB = flatbed; TR = tie ridge; RFR = recommended fertilizer rate; PS = primed seed; MD = micro-dose; IBM = intercropped mung bean; IHB = intercropped haricot bean*
### Table 6. Effect of integrated technologies on productivity of sorghum at Kobo on-farm in 2014

| Treatments          | DE   | DH   | DM  | PH   | HL  | HWt | NHPP | BY   | TKW | GY   |
|---------------------|------|------|-----|------|-----|-----|------|------|-----|------|
| NF + DS + TR        | 6.3  | 74.3 | 114.7 | 189.3 | 20.7 | 5067c | 40.0 | 12667c | 36.0 | 2199c |
| RFR+DS+TR           | 5.7  | 75.3 | 114.3 | 210.3 | 23.0 | 7467bc | 69.0 | 24444b | 34.7 | 3803ab |
| RFR+PS+TR           | 5.7  | 73.3 | 113.0 | 198.3 | 21.3 | 10333a | 101.7 | 32444a | 31.7 | 5032a |
| MD+DS+TR            | 5.0  | 73.7 | 114.3 | 197.0 | 21.0 | 6733bc | 57.7 | 21333b | 39.3 | 3520b |
| MD+PS+TR            | 5.3  | 71.7 | 112.3 | 219.3 | 20.3 | 6933bc | 76.3 | 22222b | 36.0 | 3658b |
| MD+PS+TR+IHB        | 5.3  | 74.7 | 112.7 | 194.3 | 22.3 | 8200ab | 82.3 | 24222b | 36.0 | 4328ab |
| LSD0.05             | ns   | ns   | ns   | ns   | ns   | 2503.0 | ns   | 7693.0 | ns   | 1269.4 |
| CV %                | 10.7 | 2.9  | 1.3  | 8.7  | 12.0 | 18.5 | 28.8 | 18.5  | 8.1  | 18.6 |

ns = non-significant; DE = days to emergence; DH = days to heading; DM = days to maturity; PH = plant height (cm); HL = head length; NHPP = number of heads per plot; BY = biomass yield (kg ha⁻¹); TKW = thousand kernels weight (g); GY = grain yield (kg ha⁻¹); NF = no fertilizer; DS = dry seed; TR = tie ridge; RFR = recommended fertilizer rate; PS = primed seed; MD = micro-dose; IHB = intercropped haricot bean.
Table 7. Effect of integrated technologies on productivity of pearl millet combined analysis at Kobo on-station in 2013 and 2014

| Treatments          | DE   | DH   | DM   | PH  | NTPP | HL  | HWt | NHPP | BY   | TKW   | GY   |
|---------------------|------|------|------|-----|------|-----|-----|------|------|-------|------|
| NF + DS + FB        | 6.2d-f | 51.8bcd | 87.8b-d | 169.3c-e | 4.0   | 19.8 | 6133 | 247.8 | 12267a-c | 12.1 | 2718  |
| NF + DS + TR        | 5.5f  | 52.3a-d | 91.2a  | 169.5c-e | 3.8   | 18.2 | 5333 | 258.5 | 124000-c | 12.3 | 2786  |
| NF + PS + FB        | 6.2d-f | 50.8d  | 88.0b-d | 164.3de | 3.5   | 18.5 | 4833 | 239.3 | 11200bc | 12.2 | 2773  |
| NF + PS + TR        | 7.2ab | 53.8ab | 90.0a-c | 171.5b-e | 4.0   | 19.5 | 5367 | 203.0 | 10267c   | 11.8 | 2584  |
| RFR + DS + FB       | 5.7ef | 50.8d  | 87.2cd | 159.5e  | 3.7   | 20.3 | 6900 | 289.7 | 15644a   | 12.0 | 3076  |
| RFR + DS + TR       | 5.7ef | 52.5a-d | 89.0a-d | 186.0a  | 4.0   | 19.8 | 6500 | 246.8 | 15156ab  | 11.9 | 3145  |
| RFR + PS + FB       | 6.2d-f | 51.3cd | 87.0d  | 169.8c-e | 3.5   | 20.7 | 6133 | 252.2 | 13956a-c | 12.6 | 2501  |
| RFR + PS + TR       | 6.3c-e | 52.7a-d | 89.7a-d | 174.8a-d | 4.2   | 19.2 | 5367 | 193.0 | 11400ab  | 13.3 | 2471  |
| MD + DS + FB        | 6.5b-d | 52.3a-d | 88.3b-d | 180.3a-c | 4.2   | 20.7 | 6567 | 243.0 | 14444a-c | 12.0 | 2993  |
| MD + PS + FB        | 7.3a  | 52.0a-d | 87.5b-d | 173.2a-d | 4.0   | 19.2 | 6067 | 248.7 | 11889a-c | 11.1 | 2812  |
| MD + PS + TR        | 7.0a-c | 53.3a-c | 90.3ab | 170.2c-e | 4.5   | 19.7 | 5267 | 206.2 | 11844a-c | 12.7 | 2540  |
| MD + PS + TR + MB    | 6.8a-d | 54.0a | 91.3a | 180.8a-c | 4.2   | 22.3 | 5550 | 225.2 | 11020bc  | 12.1 | 2736  |
| MD + PS + TR + HB    | 6.8a-d | 51.5cd | 89.8a-d | 179.2a-c | 4.7   | 20.2 | 4700 | 235.3 | 10911bc  | 12.5 | 2307  |
| LSD0.05             | 0.7   | 1.8   | 2.4   | 11.5  | ns   | ns   | ns   | ns   | 3676.2 | ns   | ns    |
| CV (%)              | 9.6   | 2.9   | 2.3   | 5.7   | 27.4 | 10.5 | 27.1 | 26.5 | 250     | 15.7 | 23.4  |

ns = non-significant; DE = days to emergence; DH = days to heading; DM = days to maturity; PH = plant height (cm); NTP = number of tillers per plant; HL = head length; HW = head weight; NHPP = number of heads per plot; BY = biomass yield (kg ha\(^{-1}\)); TKW = thousand kernels weight (g); GY = grain yield (kg ha\(^{-1}\)); NF = no fertilizer; DS = dry seed; FB = flatbed; TR = tie ridge; RFR = recommended fertilizer rate; PS = primed seed; MD = micro-dose; IBM = intercropped mung bean; IHB = intercropped haricot bean

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| Treatments          | DE     | DT    | DM    | PH    | CL    | NCPP  | BY    | TKW   | GY    |
|---------------------|--------|-------|-------|-------|-------|-------|-------|-------|-------|
| NF + DS + FB        | 6.5ab  | 66.5  | 104.8 | 181.8 | 19.7  | 38.8  | 10444 | 235.7 | 2139  |
| NF + DS + TR        | 6.7a   | 66.7  | 104.8 | 186.7 | 20.3  | 48.7  | 12222 | 248.7 | 2648  |
| NF+PS+FB            | 5.5bc  | 64.5  | 105.5 | 187.8 | 20.0  | 49.3  | 11111 | 261.0 | 2607  |
| NF+PS+TR            | 5.3c   | 62.7  | 103.2 | 198.0 | 20.8  | 53.0  | 12556 | 249.4 | 3120  |
| RFR+DS+FB           | 6.2a-c | 64.2  | 104.2 | 191.0 | 20.5  | 46.2  | 12556 | 239.8 | 3015  |
| RFR+DS+TR           | 6.2a-c | 64.5  | 103.2 | 205.7 | 22.2  | 65.2  | 16889 | 273.5 | 4392  |
| RFR+PS+FB           | 6.0a-c | 64.8  | 102.7 | 194.5 | 20.5  | 48.2  | 13333 | 272.2 | 3219  |
| RFR+PS+TR           | 5.3c   | 66.3  | 103.5 | 206.2 | 22.0  | 57.8  | 15000 | 251.5 | 3600  |
| MD+DS+FB            | 6.8a   | 65.8  | 102.8 | 193.5 | 20.2  | 53.7  | 13667 | 261.7 | 3480  |
| MD+DS+TR            | 6.8a   | 65.5  | 103.7 | 201.8 | 21.0  | 53.8  | 15111 | 272.0 | 3437  |
| MD+PS+FB            | 6.3a-c | 66.8  | 104.5 | 192.8 | 21.2  | 54.3  | 12222 | 240.8 | 3011  |
| MD+PS+TR            | 6.3a-c | 66.0  | 104.3 | 197.2 | 22.2  | 61.3  | 13889 | 263.3 | 3500  |
| MD+PS+TR+IBM        | 5.8a-c | 63.3  | 102.5 | 204.2 | 22.7  | 66.0  | 15556 | 288.5 | 4444  |
| MD+PS+TR+IHB        | 5.8o-c | 66.8  | 104.5 | 188.8 | 19.8  | 41.2  | 12444 | 248.8 | 2893  |
| LSO0.05             | 0.9    | ns    | ns    | ns    | ns    | ns    | ns    | ns    | ns    |
| CV (%)              | 13.5   | 5.8   | 2.9   | 7.8   | 14.2  | 28.1  | 25.3  | 12.5  | 23.5  |

ns = non-significant; DE = days to emergence; DT = days to tasseling; DM = days to maturity; PH = plant height (cm); CL = cob length (cm); NCPP = number of cobs per plot; BY = biomass yield (kg ha⁻¹); TKW = thousand kernels weight (g); GY = grain yield (kg ha⁻¹); NF = no fertilizer; DS = dry seed; FB = flatbed; TR = tie ridge; RFR = recommended fertilizer rate; PS = primed seed; MD = micro-dose; IBM = intercropped mung bean; IHB = intercropped haricot bean
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