4R SOLUTION

FINAL PROTOCOLS FOR ESTABLISHMENT OF 4R LEARNING SITES IN GHANA

Overview

The core focus of the 4R Solutions Project is to develop and disseminate nutrient management recommendations, based on principles of the 4R Nutrient Stewardship framework, to enable sustainable crop production within smallholder farming systems of northern Ghana. The 4R nutrient stewardship framework provides a basis for sustainable crop productivity intensification based on the principles the **4Rs** namely; using the **Right Source** of nutrients, applied at the **Right Rate**, in the **Right Place**, and at the **Right Time**.

While increased fertilizer application has been identified as a key entry point for enhanced crop productivity in African smallholder farms such as those of northern Ghana, farmers frequently lack tools and guidelines that help them optimize benefits of increased fertilizer use. To address this, the 4R Solutions Project seeks to provide a platform for the development and demonstration of locally adapted 4R practices that help smallholder farmers in select focal districts in northern Ghana to : (i) use the Right Source of nutrients for the various crops they grow; (ii) apply these nutrients at the right rate based on specific nutrient requirements for each crop; (iii) ensure that applied nutrients are supplied to the crop at the right place for enhanced uptake and minimal losses based on cropping systems requirements; and (iv) that nutrients are supplied at the right time in line with specific crop nutrient uptake demands.

A key component of the 4R platform will be the establishment of 4R learning sites. Established on centrally located farmer's fields within each focal district, 4R learning sites will serve as learning centres that will continually evaluate and demonstrate to farmers best crop and fertilizer management practices based on principles of the 4Rs. Participatory evaluation of crop performance and 4R practices imposed in these 4R learning sites for the various key crops in the project area will allow for adaptation of 4R practices to suit specific local conditions, presenting an increased opportunity for enhanced adoption among farmers.

These protocols provide a set of guidelines for the establishment and management of on-farm 4R learning sites for maize and groundnut which represent one of the most important cereal and legume crops in northern Ghana respectively. Developed in consultation with researchers from the Savanna Agricultural Research Institute (SARI), these protocols present standard methods that will guide key activities such as: site selection, site characterization, site preparation, planting and fertilizer application, crop management, and yield data collection in the 4R nutrient omission trials established.

1 4R learning sites

4R learning sites will be established with the aim of evaluating and demonstrating to farmers the benefits of implementing the 4Rs of fertilizer use namely; Right Source, Right Rate, Right Place and Right Time. In addition to demonstrating beneficial effects of the 4Rs of fertilizer use, 4R learning sites will adopt best crop management practices for the various crops cultivated. These practices will include aspects related to:

- Timely planting
- Use of the right seed varieties
- Right planting density
- Pest and disease control
- Timely weed management

In the first season, maize and groundnuts will be used as the key crops in the 4R learning sites. 4R learning sites for both maize and groundnuts will however be established in adjacent plots to allow for combined evaluation and demonstration of impacts of 4Rs implementation on maize and groundnuts during farmer's field days. Specific crop 4R specific details are presented below:

1.1 Maize 4R learning sites

Maize 4R learning sites will primarily set up to evaluate and demonstrate to farmers the yield and economic benefits of different fertilizer sources and different nutrient application rates.

To evaluate the right source of fertilizer, two locally available compound fertilizers namely NPK 15:15:15, and NPK 25:10:10 + 6S +3MgO + 0.3Zn will be used. The second fertilizer type will allow for the evaluation of the benefits of supply secondary and micronutrients in addition to the macronutrients N, P and K.

To evaluate the right nutrient application rate for maize, nutrients in maize 4R learning sites will be applied and low and high rates. The low and high nutrient application rates will be in line with local recommendations for medium and high target maize yields for open pollinated maize varieties (OPV) in northern Ghana. These rates are:

- Application of 60 kg N, 40 kg P_2O_5, and 40 kg K_2O per hectare for target maize yields of 2.5 – 4.5 tons per hectare
- Application of 90 kg N, 60 kg P_2O_5, and 60 kg K_2O per hectare for target maize yields of 2.5 – 4.5 tons per hectare

1.2 Groundnut 4R learning sites

Findings from the 4R baseline survey conducted and from focus group discussions with farmers in the project areas indicate that while groundnut is a key crop of interest particularly for women farmers, no fertilizer is applied during groundnuts production. Subsequently, groundnut yields have been trending downwards due to declining soil fertility. Further, groundnut yields are further declining due to root rot disease infestation.

Groundnut 4R learning sites will therefore be established to demonstrate the yield benefits of fertilizer application. Groundnut 4R learning sites will also be set up in such a way as to demonstrate best pest and disease management practices for groundnuts.

To demonstrate yield benefits of fertilizer use in groundnuts, groundnuts 4R learning sites will include two plots, with one plot receiving no fertilizer, while the second plot will have fertilizer applied. In both plots, best groundnut crop management practices will be employed so as to demonstrate to farmers right practices for pest and disease control in groundnuts.

As there are currently no fertilizer application recommendations for groundnuts in northern Ghana, fertilizer applications will be based on expected nutrient removal rates and fertilizer recommendation rates developed for other regions of the world with similarities in growing conditions. Subsequent groundnut 4R learning sites will be designed so as to fine tune these recommendations.

2 Site selection for 4R learning sites

In the first cropping season, a total of twelve (12) 4R learning sites will be established in the project area. Sites selected for establishment of 4R learning sites shall be centrally located within community settlements so as to allow easy access by farmers from surrounding communities. Each 4R learning site will therefore be located in such a way so as to be within reasonable walking distance of at least four local communities. This will allow for easy access by farmers during field days, and during demonstration of key crop and nutrient management practices.

Site selection will be conducted in early March to ensure that all 4R sites are selected well in advance of the planting season. In each of the four project districts (Kpandai, Nanumba North, Nanumba South, East Gonja) three centrally located fields will be selected.

All selected sites shall be those that are ideal for both maize and groundnut cultivation. Selected fields shall also be preferably fields where maize is currently cultivated as the key crop, with sites under long-term fallows or with groundnuts currently cultivated avoided so as to avoid possible effects of past disease infestations. In addition, selected sites should be:

- Uniform in soil type and general fertility status (e.g., no localized gravel, anthill, rock outcrop e.t.c. in parts of the field).
- Available for use as 4R learning sites for a period of at least three cropping seasons (farmer's consent to be obtained).
- Easily accessible for ease of crop monitoring, data collection, and farmer training
- Sufficiently large to allow for establishment of a minimum of six 4R learning plots each measuring 20 x 20 m, while leaving room for adequate spacing between plots.

3 4R sites characterization & demarcation

3.1 Site characterization

Selection of fields for 4R learning sites shall be followed by detailed characterization of all selected sites prior to establishment. Information for site characterization shall be obtained immediately after site selection.

Selected sites will be characterized through:

- Documentation of exact site location including GPS coordinates and name of district and community where site is located
- Documentation of site location on the slope e.g., on a gentle slope or flat land
- Documentation of estimated distance from main community settlement
- Documentation of site cropping history for the past 3 seasons including details on:
    - Crops grown in each of the seasons
    - Fertilizer use practice (type and estimated quantity of fertilizer used)
    - Organic resources use history (use of cattle manure, compost or crop residues)
    - Crop residue management practices used (buried/incorporated, burned on site, removed/taken away from the field).
    - Fallow periods (record the actual period the land was under fallow in order to know how many seasons ago this took place and it was for how long a period).
- Documentation of areas within the site previously used as animal sheds or for manure storage
- Characterization of general soil type and site condition

Site characterization shall be conducted using standard survey templates provided (Annex 1 and Annex 2). Additional details for each site can be recorded in the project field books to be provided. To ensure consistency in data collection over time and minimize chances of data mix up, a unique 4R site code will be designated by the site selection team immediately following site characterization. The unique site code will comprise of initials of the district within which the site is located, followed by a dash and the number of the 4R site within the district.

For example, the first 4R learning site in Nanumba South will be coded as NS-4R1, while the third 4R learning site in Kpandai district will be coded as K-4R3. These unique codes will be used as the reference point for all subsequent data collection and entry exercises.

3.2 Site demarcation

Immediately following site characterization, boundaries of the section of the field characterized and selected for establishment of 4R learning sites shall be demarcated using wooden pegs and strings.

The demarcated area should be rectangular in shape with a length of 80 m and a width of 60 m. Such an area will allow for the establishment of six 4R plots each measuring 20 metres by 20 metres, with paths of measuring 5 m between plots as demonstrated in figure 2 below. Demarcation will be conducted by marking out the four corners of the selected area and two central points along the long side with wooden pegs. Strings will then be used to connect the corner pegs and the central pegs to clearly mark out the boundaries of the selected area.

.

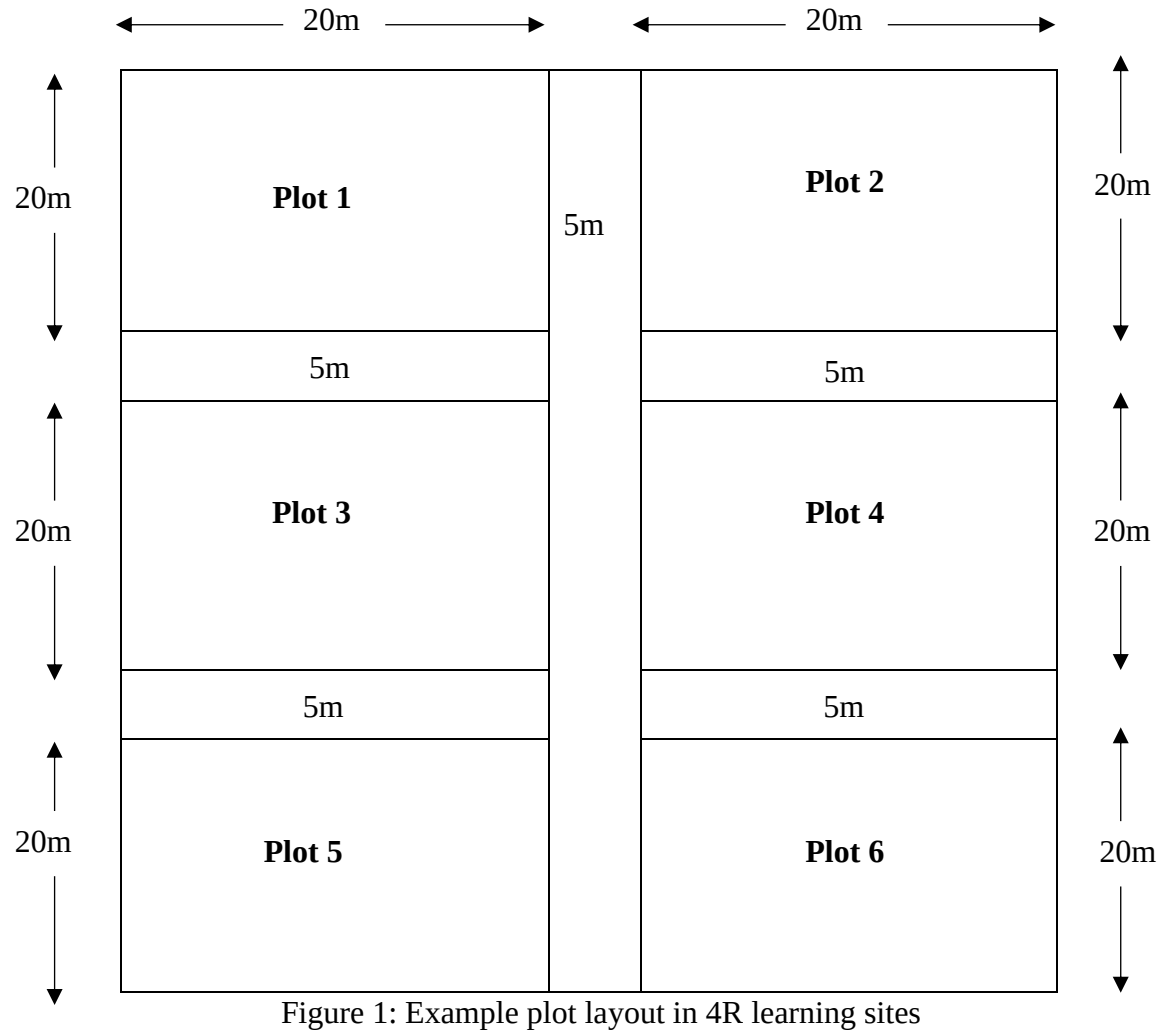

Figure 1: Example plot layout in 4R learning sites

3.3 Soil sampling

Soil sampling in 4R learning sites shall be conducted immediately following site characterization and demarcation. In each selected 4R site, soil samples will be obtained from a 0 – 20 cm depth from five (5) spots within the demarcated area using a zigzag pattern. A soil auger will be used to collect samples from each spot. A composite sample for each site shall then be obtained by thoroughly mixing samples collected from all five spots. Subsequently, two subsamples of about 500 g shall be collected and placed in sampling bags.

For each 4R site, the final bagged samples shall be clearly labelled with details of the district name, farmer/community name, site code, sampling depth and sampling date.

4 Land preparation

Land preparation in 4R learning sites shall commence in **mid April** immediately after the first rains. Early land preparation is recommended for 4R learning sites so as to ensure that fields are ready for groundnut planting which usually takes place in **early May** and shall in this case be conducted during the **first or second week of May** following consultation with local District Agricultural Extension Officers (DEAs) and community volunteers (CVAs).

Land preparation shall be conducted by use of tractors for ploughing and harrowing. Local DEAs and CVAs will be involved in monitoring and assessment of the quality of ploughing and harrowing activities so as to ensure that land preparation in all 4R sites is conducted as per the expected standards based on site specific soil and field conditions. Care should be taken to ensure that tractors are equipped with the right ploughing and harrowing equipment during ploughing and harrowing activities respectively.

5 Crop specific 4R learning sites management practices

All 4R learning sites will be researcher established and managed so as to ensure uniform and optimal management in all 4R sites. Famers in communities surrounding each 4R sites shall however be invited and involved during key crop and nutrient management practices such as planting and fertilizer application as part of 4R training. The following crop specific agronomic and nutrient management practices shall be applied for maize and groundnut respectively.

5.1 Maize

5.1.1 Seed selection

In all maize 4R sites, the OPV maize variety **Sanzal Sima** will be planted. Sufficient quantities of the Sanzal Sima maize seed will be sourced from certified and reputable seed dealers by **end of April** so as to avoid potential issues with seed availability during the planting period when demand is high.

Based on the recommended planting density for maize in the project area which requires about 30 kg of seed per hectare, maize 4R site shall require approximately 10 kg of seed. For the establishment of the required 12 maize 4R learning sites, a total of 120 kilograms of seed will be required. This total quantity includes a provision for additional seed requirement in cases where replacement planting may be required. Procured seed should be well stored in a suitable location such as the grain storage facility located at SEND offices in Salaga in readiness for planting.

5.1.2 Nutrient application rates

Nutrient application rates in maize 4R sites shall be designed to meet medium and high maize N, P and K recommendations for northern Ghana as indicated in section 1.1. These two rates will be provided using two different types of locally available compound fertilizers to give a total of four maize 4R plots in each learning site. Table 1 below provides targeted nutrient application rates for these four plots.

Table 1: Nutrient application rates for maize 4R learning sites

Plot	Fertilizer Rate Recommendation	Basal Fertilizer Source	N kg/ha	P_2O_5 kg/ha	K_2O kg/ha	S kg/ha	Zn kg/ha	B kg/ha
1	Medium	NPK 15:15:15	60	40	40	0	0	0
2	Medium	NPK+S, Zn, B	60	40	40	9	1.3	0.9
3	High	NPK 15:15:15	90	60	60	0	0	0
4	High	NPK+S, Mg, Zn	90	60	60	13	2	1.4

All fertilizer P and K, and secondary and micronutrients requirements will be applied as basal applications at two weeks after planting, while fertilizer N will be applied in two equal splits at two weeks after planting, and as top dressing at six weeks after planting. Target basal and topdress nutrient application rates are indicated in Table 2 below.

Table 2: Basal and top-dress nutrient application rates for maize 4R learning sites

Plot	Fertilizer Rate Recommendation	Basal Fertilizer Source	Basal nutrient applications (kg/ha)						Top-dress (kg/ha) N
			N	P_2O_5	K_2O	S	Zn	B	
1	Medium	NPK 15:15:15	40	40	40	0	0	0	20
2	Medium	NPK+S, Zn, B	20	40	40	9	1.3	0.9	40
3	High	NPK 15:15:15	60	60	60	0	0	0	30
4	High	NPK+S, Mg, Zn	30	60	60	13	2	1.4	60

To meet the above targeted basal and top-dress nutrient application rates at the plot level, fertilizers will be applied as per the quantities indicated in Table 3 below.

Table 3: Plot level basal and top-dress fertilizer application rates for maize 4R plots

Plot	Fertilizer Rate Recommendation	NPK 15:15:15 basal kg/plot	NPK+S, Mg, Zn basal kg/plot	Urea topdressing kg/plot
1	Medium	11	0	1.8
2	Medium	0	7.3	3.5
3	High	16	0	2.6
4	High	0	11	5.2

Based on the plot level fertilizer application rates indicated in Table 3 above, each maize 4R site will require the following quantities of fertilizers:

- 27 kg NPK 15:15:15
- 18.3 kg NPK 11:22:21 +5S + 0.72Zn + 0.5B
- 13.1 kg urea

Based on the 4R site level fertilizer requirements above, the total fertilizer requirements for maize 4R sites in the first cropping season inclusive of allowance for losses will be:

- 400 kg NPK 15:15:15
- 300 kg NPK 11:22:21 +5S + 0.72Zn + 0.5B
- 200 kg urea

5.1.3 Planting in maize 4R sites

Planting will be done at the onset of the rainy season, which is expected to take place between the **last week of June and the first week of July**. The planting exercise will be led by a team from SARI with coordination and logistics support from SEND and DEAs.

In each 4R maize plot, maize will be planted at a spacing of 80 cm (inter-row) and 40 cm (intra-row). To achieve the desired maize intra-row spacing, planting twines will be marked at 40 cm intervals (using ink or knots) and planting holes made adjacent to the marks. For efficiency, two or three planting twines can be marked and used to make holes in different plots at the same time. Hand hoes will be used to make planting holes of about 5 cm deep. Care should be taken to ensure that planting holes are made on the same side of the planting rope to avoid crooked planting rows.

After planting holes are made, two maize seeds will be planted per hole to achieve a targeted plant population of 62,500 plants/ha. Sown maize seeds will then be lightly covered with soil using hand hoes.

5.1.4 Labeling of maize 4R plots

Immediately after the planting exercise, labels that allow for the identification of individual plots in each 4R site will be prepared. These labels should be made from locally available materials in such a way that they are able to withstand effects of rain and sunshine without fading off. Prepared labels shall be installed adjacent to respective 4R plots prior to the basal fertilizer application exercise so as to guide basal fertilizer applications. For each treatment plot, the labels should include information on:

- Plot number
- Target NPK recommendation
- Basal fertilizer used
- Maize variety planted
- Planting date

Figures 2 and 3 below show an example maize 4R sites plot labels.

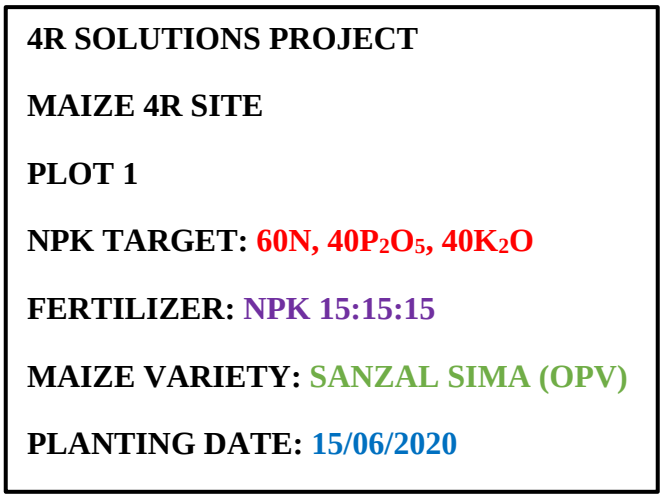

Figure 3: Example Plot 1 maize 4R site label

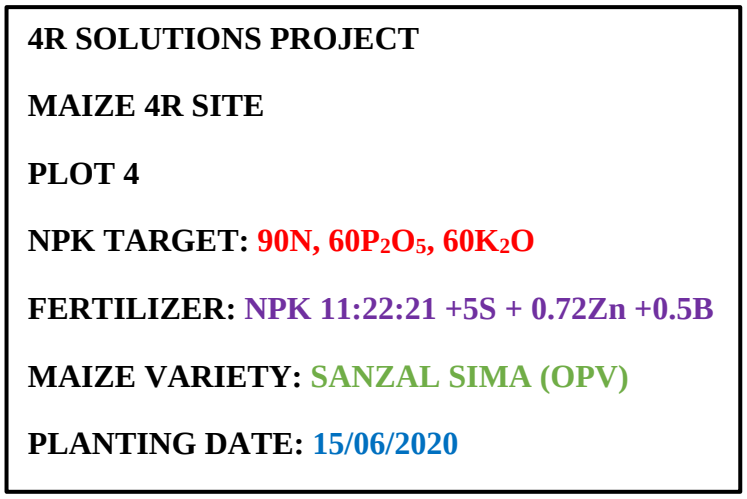

Figure 2: Example Plot 1 maize 4R site label

5.1.5 Basal fertilizer preparation

Basal fertilizer application will be conducted at two weeks after planting. To ensure efficient fertilizer application, all basal fertilizer requirements for individual treatments as presented in Table 3 shall be prepared **one week prior** to fertilizer application at the SEND storage house.

To achieve this, a digital weighing scale will be used to weigh exact quantities of each fertilizer. Weighed fertilizers will then be placed in well labeled and air tight plastic packaging materials and well stored in readiness for application at two weeks after planting.

Each maize 4R site will require:

- 1 packet of NPK 15:15:15 weighing 11 kg
- 1 packet of NPK 15:15:15 weighing 16 kg
- 1 packet of NPK 11:22:21 +5S + 0.72Zn + 0.5B weighing 7.3 kg
- 1 packet of NPK 11:22:21 +5S + 0.72Zn + 0.5B weighing 11 kg

To cover basal fertilizer applications in all maize 4R sites, the total packets of fertilizers that will require to be pre-weighed in advance will be:

- 12 packets of NPK 15:15:15 weighing 11 kg
- 12 packets of NPK 15:15:15 weighing 16 kg
- 12 packets of NPK 11:22:21 +5S + 0.72Zn + 0.5B weighing 7.3 kg
- 12 packets of NPK 11:22:21 +5S + 0.72Zn + 0.5B weighing 11 kg

5.1.6 Basal fertilizer application

Prior to basal fertilizer application, it should be ensured that all plots are adequately labeled as described in section **5.1.4** so as to ensure that only the required fertilizers are applied in each 4R plot. Based on the labels for each plot, specific fertilizer types required for each plot shall first be laid out adjacent to each treatment plot as follows:

- **Plot 1**: 1 packet of NPK 15:15:15 weighing 11 kg
- **Plot 2**: 1 packet of NPK 11:22:21 +5S + 0.72Zn + 0.5B weighing **7.3 kg**
- **Plot 3**: 1 packet of NPK 15:15:15 weighing 16 kg
- **Plot 4**: 1 packet of NPK 11:22:21 +5S + 0.72Zn + 0.5B weighing **11 kg**

A team leader from SARI shall then confirm that for all 4R plots, only the required fertilizers have been placed. This is required so as to avoid mix up of fertilizer applications between 4R plots.

All basal fertilizer applications shall be conducted by applying equal amounts of required fertilizers for each plot in a circular motion at a 5 cm radius from each planting hill. To ensure uniform fertilizer application per planting hill, pre-calibrated dollop cups that apply equal quantities of fertilizer per planting hill shall be used during fertilizer application. To calibrate the dollop cups, the required quantity of each fertilizer per plot shall be divided by the number of planting hills per plot so as to determine the amount of fertilizer required per planting hill. Dollop cups shall then be calibrated so as to ensure they apply this exact amount of fertilizer per planting hill.

After application of all required fertilizers in each plot, applied fertilizers will be lightly covered with soil around the base of each planting hill using hand hoes.

5.1.7 Weed control in maize 4R sites

Weeds infestation impairs crop growth and productivity as weeds compete with crops for nutrients and water. To control weeds in maize 4R sites, chemical and manual weeding operations will be conducted at various periods during the growing season.

The first weed control operation will be conducted at planting. This will involve the spraying of recommended pre-emergence herbicides in all maize 4R plots immediately following sowing and covering of maize seeds. In each plot, herbicide application will be conducted on the entire soil surface by uniformly spraying sufficient quantities of the herbicide using a knapsack sprayer.

Herbicides application requires the use of appropriate application equipment and protective clothing. The team from SARI will provide guidance on the safe preparation and application of recommended pre-emergence herbicides.

The second weed control operation will be conducted through manual weeding close to six weeks after planting. This weeding operation will be planned so as to be conducted just prior to top dressing fertilizer application at six weeks after planting.

5.1.8 Top dressing fertilizer application

Top dressing will be conducted at six weeks after planting after manual weeding of maize 4R plots. To ensure efficient urea top dressing, required quantities of urea fertilizer per 4R plot shall be weighed and pre-packed in advance. The following packets of urea fertilizer will require to be prepared in advance:

- 12 packets of urea weighing 1.8 kg
- 12 packets of urea weighing 3.5 kg
- 12 packets of urea weighing 2.6 kg
- 12 packets of urea weighing 5.2 kg

Immediately prior to top-dressing application, specific quantities of urea fertilizer required for each 4R plot shall first be laid out adjacent to specific treatment plot as follows:

- **Plot 1**: 1 packet of urea weighing 1.8 kg
- **Plot 2**: 1 packet of urea weighing 3.5 kg
- **Plot 3**: 1 packet of urea weighing 2.6 kg
- **Plot 4**: 1 packet of urea weighing 5.2 kg

A team leader from SARI shall then confirm that right quantity of urea fertilizer is placed adjacent to right 4R plot. This is required so as to avoid mix up of fertilizer top-dressing applications between 4R plots. Top dressing shall then be conducted by applying equal amounts of urea fertilizer around each planting hill using calibrated dollop cups.

5.1.9 Pest and disease management

Pests such as armyworms, ants and termites can cause considerable damage to maize when infestations are high. Diseases such as maize streak virus can also cause substantial damage to maize crops. All maize 4R sites will therefore be frequently monitored for pests and diseases attack and where any pest or disease attack is identified, appropriate control measures shall be applied based on advice from the local research team.

5.1.10 Yield assessment in 4R sites

To quantify maize yield responses to nutrient applications, maize crops in all treatment plots will be harvested after the crop has reached physiological maturity. In each treatment plot, a net plot comprising of 4 rows x 3 m will be demarcated within a central location in each treatment plot so as to avoid edge effects. After net plot demarcation, all the plants in the net-plot will be cut at the soil surface and the number of plants counted and recorded in a harvest form to be provided. The total number of ears will then be counted, cobs removed and total cob weight determined using a weighing balance accurate to two decimal places. All stover from the net plot will also be weighed and the total weight recorded.

From the total cobs and stover measured, five (5) representative cobs and stovers will be randomly selected and fresh weights taken. The 5 cobs constitute a sub-sample and their grains and cores will be separated and their fresh weights separately determined. Selected stovers will be cut into 5 cm strips, well mixed and a subsample of about 200 g taken. The three sub-sample plant parts (grain, cores and stover) will then be packed and clearly labelled, and subsequently oven dried (60 ºC for 48 hours). Oven dried samples will be reweighed and dry weights recorded for dry matter yield determination. Sub-samples of dried and weighed grain and stover shall then be well labelled and preserved for grain and stover nutrient concentration analysis.

5.2 Groundnut

5.2.1 Seed selection

In all groundnut 4R sites, the **Sarinut 2** variety will be planted. Sufficient quantities this groundnut variety will be sourced from certified and reputable seed dealers by **mid April** so as to avoid potential issues with seed availability during the planting period when demand is high.

Based on the recommended planting density for groundnut in the project area which requires about 70 kg of seed per hectare, one groundnut 4R site shall require approximately 10 kg of seed. For the establishment of the required 12 groundnut 4R learning sites, a total of 120 kilograms of seed will be required. This total quantity includes a provision for additional seed requirement in cases where replacement planting may be required. Procured seed should be well stored in a suitable location such as the grain storage facility located at SEND offices in Salaga in readiness for planting.

5.2.2 Nutrient application rates

Groundnut 4R sites shall be designed to demonstrate to farmers the yield benefits of balanced fertilizer application given the traditional practice of cultivating groundnut with no fertilizer applied. Subsequently, one groundnut 4R plot shall have no fertilizer applied, while the second plot shall have compound fertilizer applied so as to provide rates close to 20 kg N, 20 kg P, and 30 kg K per hectare based on expected groundnut nutrient uptake requirements, and the ability of groundnut to fix N. Table 4 below indicates actual nutrient application rates for groundnut 4R plots.

Table 4: Nutrient application rates for maize 4R learning sites

Plot	Fertilizer Rate Recommendation	Basal Fertilizer Source	N kg/ha	P_2O_5 kg/ha	K_2O kg/ha	S kg/ha	Zn kg/ha	B kg/ha
1	Farmer practice	None	0	0	0	0	0	0
2	Best management	NPK+S, Zn, B	20	40	38	9	1.3	0.9

Fertilizer application in the 4R best management plot will be applied as basal application in form of compound NPK fertilizer (11:22:21 + 5S +0.72Zn + 0.5B). Actual plot level fertilizer applications are indicated in Table 5 below.

Table 5: Plot level basal and top-dress fertilizer application rates for maize 4R plots

Plot	Fertilizer Rate Recommendation	NPK basal kg/plot
1	Farmer practice	0
2	Best management	7.2

Based on the plot level fertilizer application rates indicated in Table 3 above, each maize 4R site will require 7.2 kg of NPK 11:22:21 +5S + 0.72Zn + 0.5B. To meet fertilizer needs in all 12 groundnut 4R sites inclusive of allowance for losses during weighing, the total amount of fertilizer required will be:

- 100 kg NPK 11:22:21 +5S + 0.72Zn + 0.5B

5.2.3 Fertilizer preparation and application in groundnut 4R sites

a) Fertilizer preparation

Required basal fertilizer in groundnut 4R sites shall be applied at planting. Planting will be done immediately after the first rains. This is expected take place during the **first or second week of May**. The planting exercise will be led by a team from SARI with coordination and logistics support from SEND and DEAs.

To ensure efficient fertilizer application at planting, fertilizer required in groundnut 4R sites as presented in Table 5 shall be prepared **one week prior** to fertilizer application at the SEND storage house. To achieve this, a digital weighing scale will be used to weigh 7.2 kilograms of the selected NPK fertilizer. Weighed fertilizers will then be placed in well labeled and air tight packaging materials and well stored in readiness for application at two weeks after planting. To cover fertilizer application in all 12 groundnut 4R learning sites, the total packets of fertilizers that will require to be pre-weighed in advance will be:

- 12 packets of NPK 11:22:21 +5S + 0.72Zn + 0.5B each weighing 7.2 kg

b) Fertilizer application

To ensure right application of fertilizer, fertilizers should be applied before groundnut seeds are sown. To apply fertilizer, groundnut planting rows shall first be prepared based on the recommended spacing of 50 cm (inter-row) and 15 cm (intra-row). To achieve the desired spacing, planting rows that are 5 cm deep shall be made across plots using hand hoes. Wooden pegs shall be used to demarcate row positions to ensure consistent between row spacing of 50 cm.

Fertilizer application shall then be conducted in only one of the 4R plots through banding. For this, the required quantity of fertilizer at plot level shall be uniformly through banding on one side of the planting furrows prepared. To achieve this, prepared planting twines shall be placed at the center of the planting rows by sticking each end of the planting twine on opposite ends of the planning row. Fertilizer shall then be applied one side of the planting row.

5.2.4 Planting in groundnut 4R sites

After fertilizer has been applied in one of the 4R plots, groundnuts will be sown in both plots. In each row, one groundnut seed shall be sown by hand at a spacing of 15 cm. To achieve the desired intra-row spacing, planting twines will be marked at 15 cm intervals (using ink or knots) and seeds sown adjacent to these markings. To prevent seeds coming into direct contact with applied fertilizer in the plot with fertilizer applied, all seeds shall be sown on the other side of the planting twine as demonstrated in figure 4 below. Once all seeds are sown, planting rows will be lightly covered with soil using hand hoes.

Figure 4: Example recommended placement of seeds and fertilizer in groundnut 4R sites

5.2.5 Labeling of groundnut 4R plots

Immediately after the planting exercise, labels that allow for the identification of individual plots in each 4R site will be prepared. These labels should be made from locally available materials in such a way that they are able to withstand effects of rain and sunshine without fading off. Prepared labels shall be installed adjacent to respective groundnut 4R plots immediately after sowing and fertilizer application. In each groundnut 4R site, the two groundnut plots shall be labeled as shown in figures 5 and 6 below.

4R SOLUTIONS PROJECT

GROUNDNUT 4R SITE

PLOT 2: BEST MANAGEMENT

NPK TARGET: 20N, 40P_2O_5, 38K_2O

FERTILIZER: NPK 11:22:21 +5S + 0.72Zn +0.5B

MAIZE VARIETY: SARINUT 2

PLANTING DATE: 10/05/2020

Figure 5: Example Plot 2 groundnut 4R site label

4R SOLUTIONS PROJECT

GROUNDNUT 4R SITE

PLOT 1: FARMER PRACTICE

NPK TARGET: 0N, 0P_2O_5, 0K_2O

FERTILIZER: NONE

MAIZE VARIETY: SARINUT 2

PLANTING DATE: 10/05/2020

Figure 6: Example Plot 1 groundnut 4R site label

5.2.6 Weed control in groundnut 4R sites

Weeds infestation impairs crop growth and productivity as weeds compete with crops for nutrients and water. To control weeds in groundnut 4R sites, chemical and manual weeding operations will be conducted at various periods during the growing season.

The first weed control operation will be conducted at planting. This will involve the spraying of recommended pre-emergence herbicides in all groundnut 4R plots immediately following sowing and fertilizer application.

In each groundnut plot, herbicide application will be conducted on the entire soil surface by uniformly spraying sufficient quantities of the herbicide using a knapsack sprayer.

Herbicides application requires the use of appropriate application equipment and protective clothing. The team from SARI will provide guidance on the safe preparation and application of recommended pre-emergence herbicides.

The second weed control operation will be conducted through manual weeding at about four weeks after planting. During the course of the growing season, weekly monitoring of groundnut 4R sites for weed infestation shall be conducted and decisions on weed control made based on the intensity of weed infestation.

5.2.7 Pest and disease management

Pests such as armyworms, ants and termites can cause considerable damage to maize when infestations are high. Diseases such as maize streak virus can also cause substantial damage to maize crops. All maize 4R sites will therefore be frequently monitored for pests and diseases attack and where any pest or disease attack is identified, appropriate control measures shall be applied based on advice from the local research team

5.3 Post-harvest management of 4R sites

The multi-seasonal design of established 4R nutrient omission trials requires that treatment plots are established on the same exact spot in subsequent seasons. To ensure this is the case in all NOT sites, the following guidelines shall be followed prior to and after harvesting to manage specific aspects in the project area.

5.3.1 Managing fires in trial sites

A common practice in the project area is the burning of fields during the dry season as a form or crop residue management, and for the control of weeds and rodents. Fires established on adjacent fields can quickly spread to NOT fields, and this can potentially affect subsequent crop yield response patterns. It will therefore be imperative to ensure that all NOT sites are kept fire free by controlling weed and crop residues in and around NOT trial locations.

To achieve this, a fire belt with a width of 2 m will be established along the boundaries of all NOT sites by spraying recommended herbicides along the boundaries of NOT experimental areas and farmer practice areas in **mid-October**.

To further reduce the risk of fire in NOT sites, all crop residues remaining after harvest will be cut at the ground level, cut into pieces and well incorporated into the soil.

5.3.2 Managing location of NOT trial plots

To ensure that exact treatment plot locations are maintained in subsequent cropping seasons, metallic pegs will be installed on the edges of each treatment plot in place of the previously installed wooden pegs. These metallic pegs will be well hammered into the ground to prevent easy removal, and farmers advised to continuously monitor the presence of these pegs.

Treatment plot locations can also change when the NOT site is tractor ploughed during land preparation, making it difficult to locate exact plot boundaries in subsequent seasons. To prevent this, land preparation in NOT sites after the first cropping season will only be conducted through manual hand tillage. This will be conducted in such a way that only the areas within the treatment plot that are expected to be cropped will be tilled, with the boundaries between plots maintained untilled.

The project team should also make sure to sensitize farmers on the need to maintain exact trial plot locations, and advise them to how best to maintain and manage treatment plot locations.

Annex

Annex 1 (Site location form)

District Name	**Community**	**NOT CROP**	**SITE CODE**	**Selection Category**	**Latitude**	**Longitude**	**Farm Position** (upland, slope or bottom land)

Annex 2 (Site history form)

Farmer Name	**Site CODE**	**Cropping system** (monocrop or mixed cropping) State key crop	**Fallow period in last 10 years?** (year-year)	**Crop Residue Management** (ploughed back, burned or surface applied)	**Fertilizer use** (Yes or NO)	**Animal manure use** (Yes or NO)	**Crops grown in previous three seasons** (1st S is immediate last season and 3rd season is the third season back		
							1st S crops	**2nd S crops**	**3rd S crops**

Annex 3 (NOT experiments management form)

Site CODE	Land preparation		Planting date	Dates of other field activities						
	Date	Method		75 % Emergence	Gapping	Replace ment	Basal fert application	1st Weeding date	Top dressing application	2nd Weeding date