

Supplementary Materials: Table S1 Farm crop selection, ZBNF mulch selection and management history

District	Farm	Crop Selected	Growing Season (d)	Mulch material used in ZBNF treatment	Soil Texture	Approx time land has been cultivated (yrs)	Management before experiment
Anantapur	A1	Groundnut	90-120	Groundnut Husk	Sandy Loam	Unknown	Conventional
	A2	Groundnut	90-120	Groundnut Husk	Sand	Unknown	Organic
	A3	Groundnut	90-120	Groundnut Husk	Sandy Loam	30	Conventional, then ZBNF (last 2 yrs)
Kadapa	Ka1	Tomato	60-90	Sunhemp and Avisa Leaves	Sandy Clay Loam	8	Conventional
	Ka2	Chilli	75-90	Groundnut Husk	Sand	6	Conventional
	Ka3	Groundnut	90-120	Groundnut Husk	Loamy Sand	10	Conventional & Organic
Krishna	Kr1	Okra	40-45	Paddy Straw	Clay	20	Unknown
	Kr2	Okra	40-45	Paddy Straw	Clay	15	Conventional
	Kr3	Aubergine	65-80	Paddy Straw	Clay	10	Conventional
	Kr4	Tomato	60-90	Paddy Straw	Sand	12	Conventional
Nellore	N1	Okra	40-45	Paddy Straw	Sandy Loam	30	Unknown
	N2	Okra	40-45	Paddy Straw	Clay	40	Unknown
	N3	Groundnut	90-120	Groundnut Husk	Sand	27	Unknown, then ZBNF (last 2 yrs)
	N4	Okra	40-45	Paddy Straw	Loamy Sand	35	Conventional, then ZBNF (last 3 yrs)
Prakasam	P1	Cluster Bean	85-95	Chickpea Husk	Clay	15	Conventional
	P2	Cluster Bean	85-95	Groundnut Husk	Sandy Loam	Unknown	Conventional

	P3	Okra	40-45	Groundnut Husk	Clay	Unknown	Conventional
	P4	Aubergine	65-80	Paddy Straw	Sandy Loam	Unknown	Conventional
Visakhapatnam	V1	Radish	45-60	Paddy Straw	Sandy Clay Loam	0.33	Conventional
	V2	Okra	40-45	Paddy Straw	Sandy Clay Loam	15	Conventional

Table S2. Growing protocol for aubergine

	Aubergine		
	Conventional	Organic	ZBNF
Seed Rate	2.34 g/plot 60 cm x 60 cm (plant-plant x row-row)	2.34 g/plot 60 cm x 60 cm (plant-plant x row- row)	2.34 g/plot 60 cm x 60 cm (plant-plant x row- row)
Irrigation	7-10 d intervals	7-10 d intervals	7-10 d intervals
Thiaram or Mancozeb seed treatment	3 g/kg seed	-	-
Trichoderma seed treatment	-	4 g/ kg seed	-
Bijamrita seed treatment	-	-	3 l/kg seed
Farmyard Manure	54 kg/plot	54 kg/plot	-
Urea	0.8 kg/plot split over 3 doses (30, 60 and 75 d after sowing)	-	-
Diammonium phosphate (DAP)	0.5 kg/plot	-	-
Potash (MOP)	0.36 kg/plot	-	-
Micronutirents	5 g dissolved in 1 l water/ plot applied as a foliar spray	-	-
Solid Jiramrita	-	-	1.8 kg/plot
Liquid Jiramrita	-	-	1.8 l/plot every 10 d
Panchagavya or Sapthadhanyankura tonic	-	-	45 ml/plot during flowering stage

Vermicompost	-	3.6 kg/plot as a top dressing	-
Biofertilizers	-	18 g/plot each Azospirillum and Phosphobacteria	-
Neem Cake	-	18 g/ plot	-
Mulching	-	-	Crop residue 5cm thick applied to the surface

Table S3. Growing protocol for chilli

	Conventional	Chilli Organic	ZBNF
Pre-sowing Land preparation	35 g/plot carbofuran granules	0.89 kg Neem cake	0.89 kg Neem cake
Seed Rate	3.55 g/plot 60 cm x 60 cm (plant-plant x row-row)	3.55 g/plot 60 cm x 60 cm (plant-plant x row-row)	3.55 g/plot 60 cm x 60 cm (plant-plant x row-row)
Irrigation	5-7 d intervals	5-7 d intervals	5-7 d intervals
Imidacloprid seed treatment	8 g/kg seed plus 3 g/kg seed Captan/ Thiram/ Mancozeb and 150 g/kg seed trisodium orthophosphate	-	-
Trichoderma seed treatment	-	4 g/kg seed plus 10 g/kg seed <i>Pseudomonas</i> sp.	-
Bijamrita seed treatment	-	-	200 ml/kg seed
Farmyard Manure	88.95 kg/plot	88.95 kg/plot	-
Urea	106 g/plot split over 3 application (30, 60 and 90 d after sowing)	-	-
Diammonium phosphate (DAP)	213 g/plot	-	-
Potash (MOP)	106 g/plot	-	-
ZnSO ₄	Foliar spray of 0.5% tree time at 40, 50 and 60 d after sowing	-	-

Solid Jiramrita	-	-	3.55 kg/plot
Liquid Jiramrita	-	-	1.77 l/plot every 15 d
Panchagavya Sapthadhanyankura tonic	or -	45 ml/plot during flowering stage	45 ml/plot during flowering stage
Vermicompost	-	17.79 kg/plot	-
Biofertilizers	-	1-1.25 kg Azospirillum/ Azotobacter	-
Mulching	-	-	Crop residue 5cm thick applied to the surface

Table S4. Growing protocol for growing cluster bean

	Cluster Bean		
	Conventional	Organic	ZBNF
Seed Rate	36g/plot	36g/plot	36g/plot
	15 cm x 45 cm (plant-plant x row- row)	15 cm x 45 cm (plant- plant x row-row)	15 cm x 45 cm (plant-plant x row- row)
Irrigation	Immediately after sowing and every 7- 10 d thereafter	Immediately after sowing and every 7- 10 d thereafter	Immediately after sowing and every 7- 10 d thereafter
Carbendazim seed treatment	2 g/kg seed	-	-
Trichoderma seed treatment	-	4 g/kg seed	-
Bijamrita seed treatment	-	-	3 l/kg seed
Farmyard Manure	24 kg/plot	24 kg/plot	-
Compost	-	20 kg/plot	-
Urea	2 x 0.8 kg/plot doses (basal dose & after 30 d)	-	-
Diammonium phosphate (DAP)	1.6 kg/ plot	-	-
Potash (MOP)	0.3 kg/ plot	-	-
Solid Jiramrita	-	-	4 kg/plot
Liquid Jiramrita	-	-	4 l/plot every 10 d
Panchagavya	-	5% spray	-
Sapthadhanyankura tonic	-	-	45 ml/ plot

Vermicompost	-	2.5 kg/plot as top dressing	-
Biofertilizers	-	7.2 g/plot each Azospirillum and Phosphobacteria	-
Neem Cake	-	4 kg/ plot	-
Mulching	-	-	Crop residue 5cm thick applied to the surface

Table S5. Growing protocol for groundnut

	Groundnut		
	Conventional	Organic	ZBNF
Seed Rate	0.75 kg/plot 10 cm x 30 cm (plant-plant x row-row)	0.75 kg/plot 10 cm x 30 cm (plant-plant x row-row)	0.75k g/plot 10 cm x 30 cm (plant-plant x row-row)
Irrigation	7-10 d intervals	7-10 d intervals	7-10 d intervals
Carbendizm & Imidacloprid seed treatment	Carbendizm -2 g/kg seed plus Imidacloprid – 2 ml/ l water	-	-
Trichoderma seed treatment	-	4 k/ kg seed	-
Bijamrita seed treatment	-	-	200 ml/ kg seed
Farmyard Manure	-	54 kg/plot	-
NPK 12:16:20	3 kg/plot	-	-
Gypsum	165 g/plot	-	-
ZnSO ₄	16.5 g/plot	-	-
FeSO ₄	300ml/ plot	-	-
Solid Jiramrita	-	-	330 g/plot
Liquid Jiramrita	-	-	330 ml/ plot every 15 d
Panchagavya or Sapthadhanyankura tonic	-	-	45 ml/plot during flowering stage
Vermicompost	-	3 kg/plot	-
Vermiwash (if available)	-	1.8 l/ plot asfoliar spray or top dressing	-

Biofertilizers	-	18 g/plot each Azospirillum and Phosphobacteria	-
Neem Cake	-	0.9 kg/plot	-
Mulching	-	-	Crop residue 5cm thick applied to the surface

Table S6. Growing protocol for okra

	Conventional	Okra Organic	ZBNF
Seed Rate	54 g/plot 60 cm x 30 cm (plant-plant x row-row)	54 g/plot 60 cm x 30 cm (plant-plant x row-row)	54 g/plot 60 cm x 30 cm (plant-plant x row-row)
Irrigation	7- 10 d intervals	7- 10 d intervals	7- 10 d intervals
Imidachloprid seed treatment	5 g/kg seed	-	-
Trichoderma seed treatment	-	4 g/kg seed	-
Bijamrita seed treatment	-	-	3 l/ kg seed
Farmyard Manure	54 kg/ plot	54 kg/ plot	-
Urea	1 kg/ plot, split over 3 doses (333 g/ plot: basal, after 30 d & after 45 d)	-	-
Diammonium phosphate (DAP)	0.5 kg/ plot	-	-
Potash (MOP)	0.36 kg/plot	-	-
Micronutrients	5 g to be mixed in 1 l water and applied as foliar spray	-	-
Solid Jiramrita	-	-	1.8 kg/plot
Liquid Jiramrita	-	-	1.8 l/plot every 10 d
Panchagavya Sapthadhanyankura tonic	or -	-	45ml/ plot

Vermicompost	-	3.6 kg/plot as top dressing	-
Vermiwash (if available)	-	1.8 l/plot as foliar spray or top dressing	-
Biofertilizers	-	18 g/plot each Azospirillum and Phosphobacteria	-
Neem Cake		0.9 kg/ plot	
Mulching	-	-	Crop residue 5cm thick applied to the surface

Table S7. Growing protocol for radish

	Radish		
	Conventional	Organic	ZBNF
Seed Rate	36 g/plot 10 cm x 15 cm (plant-plant x row-row)	36 g/plot 10 cm x 15 cm (plant-plant x row-row)	36 g/plot 10 cm x 15 cm (plant-plant x row-row)
Irrigation	7- 10 d intervals	7- 10 d intervals	7- 10 d intervals
Thiaram or Mancozeb seed treatment	3 g/ kg seed	-	-
Trichoderma seed treatment	-	4 g/ kg seed	-
Bijamrita seed treatment	-	-	3 l/ kg seed
Farmyard Manure	90 kg/ plot	-	-
Urea	1 kg/ plot split over 2 doses (500 g/ plot: basal & after 30 d)	-	-
Diammonium phosphate (DAP)	2 kg/ plot	-	-
Potash (MOP)	1 kg/ plot	-	-
Solid Jiramrita	-	-	4.4 kg/ plot
Liquid Jiramrita			4.4 l/plot every 10 d
Panchagavya	-	5% spray	-
Sapthadhanyankura tonic	-	-	45 ml/plot at flowering stage
Vermicompost	-	9 kg/plot as top dressing	-

Biofertilizers	-	10 g/plot each Azospirillum, Phosphobacteria and K mobiliser	-
Neem Cake	-	0.6 kg/plot	-
Oil seed cake	-	2 kg/plot	-
Bone meal	-	5 kg/plot	-
Mulching	-	-	Crop residue 5cm thick applied to the surface

Table S8. Growing protocol for tomato

	Conventional	Tomato Organic	ZBNF
Pre-sowing Land preparation	0.28 g/plot carbofuran granules	0.64 kg – 0.8 kg Neem cake	0.64 kg – 0.8 kg Neem cake
Seed Rate	1.12 g/plot 60 cm x 60 cm (plant-plant x row-row)	1.12 g/plot 60 cm x 60 cm (plant-plant x row-row)	1.12 g/plot 60 cm x 60 cm (plant-plant x row-row)
Irrigation	10-15 d intervals	10-15 d intervals	10-15 d intervals
Thiaram or Mancozeb seed treatment	3g /kg seed	-	-
Trichoderma seed treatment	-	4 g/kg seed Plus 200g each of N fixing and PSB in 300-400ml water	-
Bijamrita seed treatment	-	-	3 l/ kg seed
Farmyard Manure	48-50 kg/plot	48-50 kg/plot	-
Urea	20 g dissolved in 1 l water/plot	-	-
Ammonium Nitrate	0.32-0.48 kg split over 3 applications (30, 45 and 60 d after transplanting)	-	-
Potash (MOP)	0.32 kg/plot	-	-
Super Phosphate	1.2 kg/plot	-	-
ZnSO ₄	0.08 kg/plot	-	-
Borax	0.06-0.10 kg/plot	-	-

Solid Jiramrita	-	-	1.6 kg/plot
Liquid Jiramrita	-	-	1.8 l/plot every 10 d
Panchagavya Sapthadhanyankura tonic	or -	-	45 ml/plot during flowering stage
Vermicompost	-	8-12 kg/plot	-
Neem Cake	-	100g suspended in 1 l water/ plot	-
Mulching	-	-	Crop residue 5cm thick applied to the surface

Table S9. Pest and disease management strategies in conventional, organic and ZBNF

Pest/ Disease	Management Strategy		
	Conventional	Organic	ZBNF
Shoot and fruit borer	Quinolphos or Prophenophos (2 ml/l) 1 l per plot Spray twice at 10 d intervals during vegetative and fruit development stage	Pheramone traps (1 per plot) Neem oil or 5% NSKE Trichogramma 180 ml per plot Four times at 7 d intervals	Pheramone traps (1 per plot) Agnasthram (27 ml/plot) Neemasthram (27 ml/plot)
Sucking pest (white fly, aphids leaf hopper and thrips)	Dimethoate (3 ml/l) Spray twice at 10 d intervals 1 l per plot Green lace wing bugs 1st instar larvae (36/plot)	Grease coated bottles or yellow plates (1 per Plot) Neem oil or 5% NSKE	Yellow sticky plates (1 per plot) Neemasthram (1.8 l/plot)
Yellow vein mosaic	Dimethoate (3 ml/l) Spray twice at 10 d intervals 1 l per plot	Grease coated bottles or yellow plates (1 per Plot) Neem oil or 5% NSKE	Yellow sticky plates (1 per plot) Neemasthram (1.8 l/plot)
Epilachna beetle	Quinolphos or Prophenophos (2 ml/l) 1 l per plot Triazophos 40%EC (2.5 ml/l)	Neem oil or 5% NSKE	Agnasthram (27 ml/plot) Neemasthram (1.8 l/plot)
Damping Off	Copper oxychloride (2.5g/l) 144 l/plot	Seed treatment, bio-fertilizers and FYM, as described in crop growing protocol	Bijamrita seed treatment as described in crop growing protocol
Pod borer	Carbaryl 50WP (2 g/l) or Quinalphos 25EC (2 ml/l) 1 l per plot	-	Neemasthram (1.8 l/plot) Agnasthram (27 ml/plot)
Powdery mildew	Wettable sulphur (2 g/l). Spray 3 times at 15 d intervals. 1 l per plot	-	Cow milk (27 ml/plot) or Fermented butter milk (54 ml/plot)
Leaf spot	Mancozeb (2 g /l) or copper oxychloride (2.5 g/l) 1 l per plot	Early removal of infected plants. 10 g of <i>Trichoderma</i> or <i>Pseudomonas</i> Sp. in 1 l water for spraying	Neemastram (89 ml/ plot)
Leaf miner	Carbofuran (3%) 144 g per plot	Yellow sticky plates (1 per plot)	Yellow sticky plates (1 per plot) Neemasthram (1.8 l/plot)

Figure S1. Example instruction booklet for implementation of experimental design

Farm Reference	District	NFF Name
Name:		
Farm:		
District:		
<h2 style="margin: 0;">ZBNF Experimental Design</h2>		
<p>1 Introduction</p> <p>This booklet contains all the information you will need to conduct your field experiment (although don't be afraid to ask questions if you are unsure). The experiment is designed to examine the differences between conventional farming, organic farming and ZBNF. Particularly the effects they have on soil properties and yield. <u>Make sure read this booklet in full before starting any work on your experiment.</u></p> <p>It is vital, in order to make this a fair test and a good research piece, that all three farming practices are conducted properly, according to the appropriate guidelines. It is also important that you keep good records, as your experiment will undergo an audit/ inspection from a third party.</p> <p>It is important you keep a record of everything you do on the plots, so make sure you have a notebook/diary that is used solely for this experiment. Use this to record things like:</p> <ul style="list-style-type: none"> ➤ Description of activities e.g. weeding ➤ What was added e.g. Jiwamrita, fertilizers, pesticides (with quantities and plot number applied to) ➤ Any observations on crop health, with plot number (poor/ fair/ good) ➤ Always note the date and the plot number of the activity <p>Important: once you have filled in a page of this booklet, take a picture of it and send it to the Whatsapp group. This booklet is tailored to you so if you lose it ask your research coordinator or Sarah to send you another copy.</p>		
1		



Farm Reference

District

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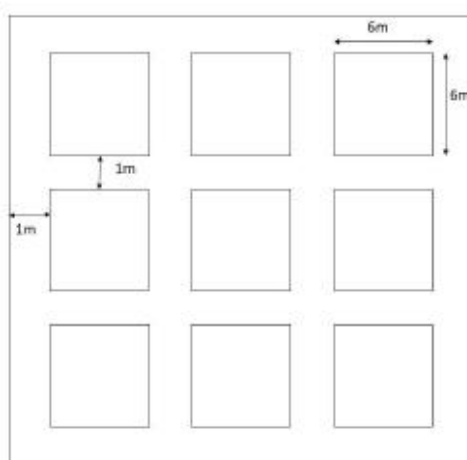
2 Setting up the experiment

1. You will need:

- 2 tape measures (one 30m, one 3m)
- Sticks (bamboo or similar) – 4 big, 40-50 smaller
- You may also need someone to help you

Note: wind in the tape measure after each measurement, this will stop it getting tangled and makes it easier to keep it tight and straight for each measurement

2. We are going to measure out nine 6m x 6m plots, with a 1m path in between, like the drawing below



Example of plot experiment, corner of each plot is marked with labelled sticks, clear path between plots.



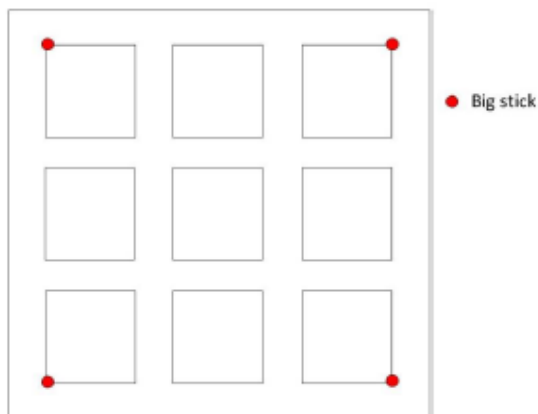


Farm Reference

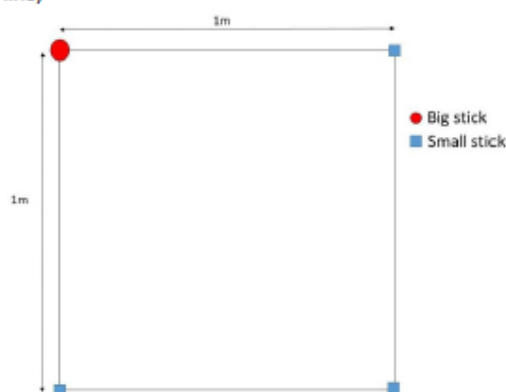
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3. First we are going the four plot corners shown below, with the 4 big sticks (the 1m boundary will be added last)



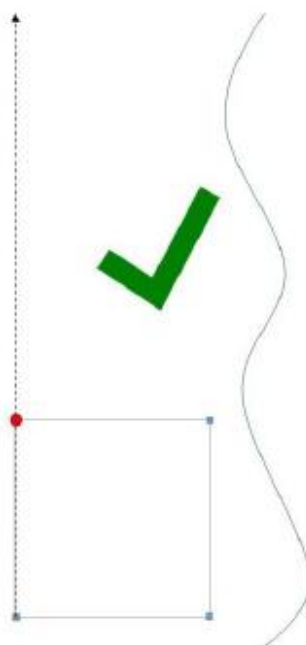
4. Place a big stick in the ground near the corner of the field you are going to use for your experiment (making sure there is enough space to add the 1m path round the outside later)
5. Using the shorter tape measure, create a 1m x 1m square with 3 smaller sticks (this square will help us measure in a straight line)



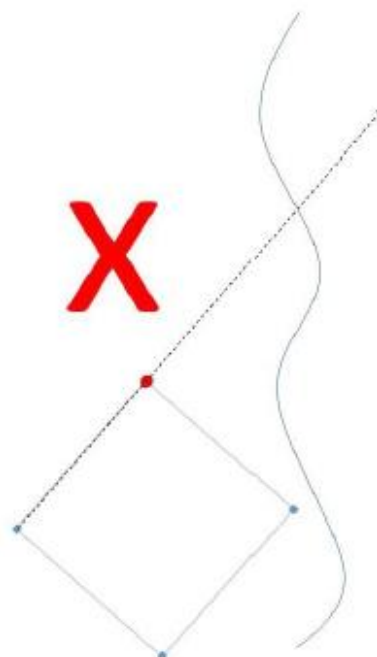
6. When positioning the small sticks, make sure the sides that are connected to the big stick are pointing in a direction where you have a clear path for 20m (see drawing below)



Farm Reference

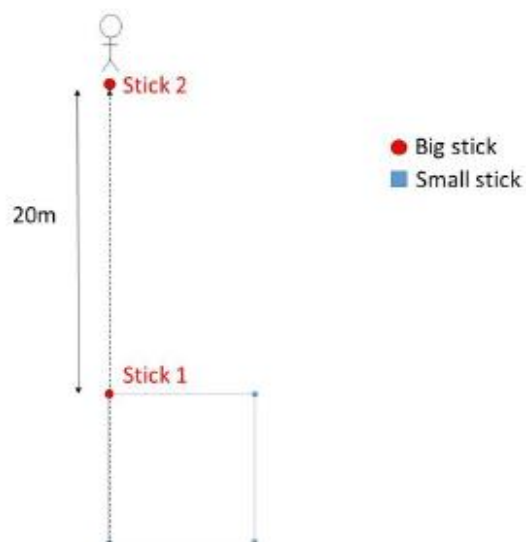


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7. From the big stick, keeping the tape measure tight and low to the ground, walk in a straight line for 20m
- Making sure that the big stick, the small stick, and you are all in a straight line
 - When you are happy, place a big stick at the 20m mark





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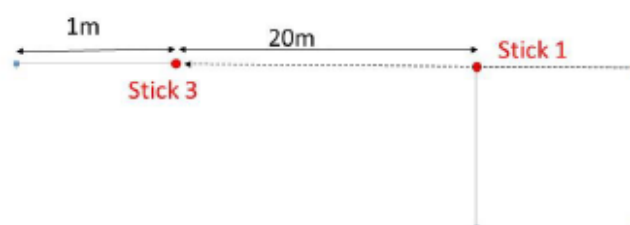
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8. Wind in the tape measure and return to big stick 1
9. Repeat step 7 at a right angle to your first measurement
 - a. This time also place a big stick and 20m, and a small stick at 21m

● Stick 2

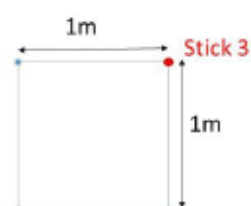
● Big stick
■ Small stick



10. Using the small stick that is already in place, create another 1m square another 1m x 1m square around big stick 3 with small sticks (don't move the big stick or the first small stick that is already in place)

● Stick 2

● Big stick
■ Small stick



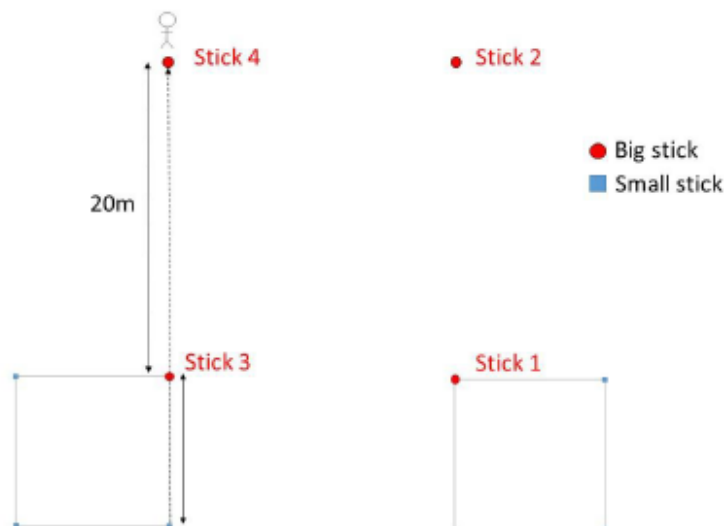


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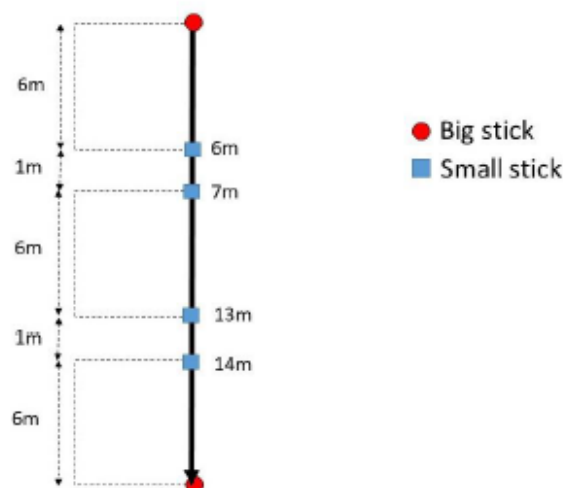
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11. Keeping the tape measure tight and low to the ground, walk in a straight line for 20m and put big stick 4 in place (but be prepared you may have to move it during step 12)



12. Starting from stick 2, keeping the tape measure tight and low to the ground, measure the distance between big stick 2 and 4 to check it is 20m. If it isn't move stick 4 accordingly (making sure to keep the distance between stick 3 and 4 also 20m)
13. Double check the distances between all four of the big sticks is 20m
14. Once you are happy with the positioning of the four big sticks 20m apart, you can start to mark out the rest of the plot boundaries
15. Making sure you keep the tape measure tight and straight, lay out the tape measure between two of the big sticks
16. Place sticks at the 6m, 7m, 13m and 14m mark as shown below



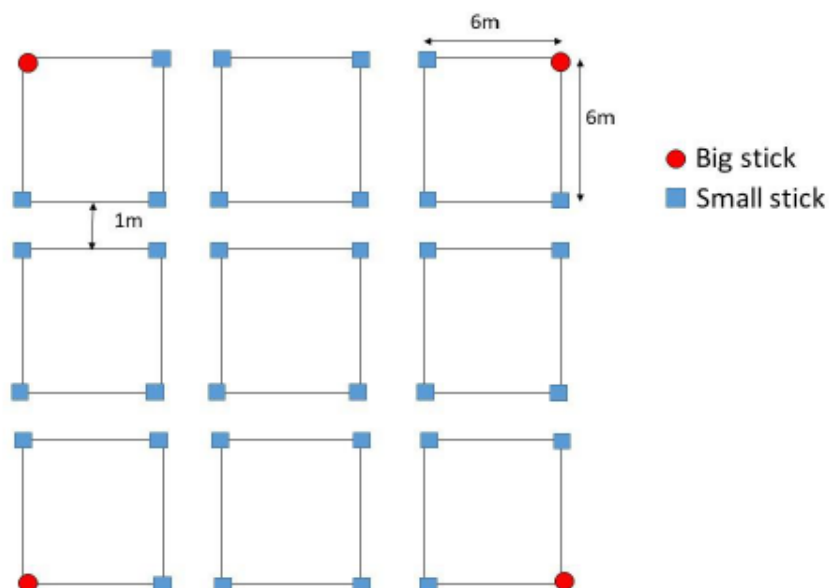


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17. Repeat this on all four sides first, and then across the middle as follows:



18. Finally, using the remaining small stick, mark out a 1m path around your plots (as seen on page 2)

19. Next you need to number and label the plots according to the treatments drawing below. Make sure to label them in a way that is weather proof! (e.g. paint the sticks)

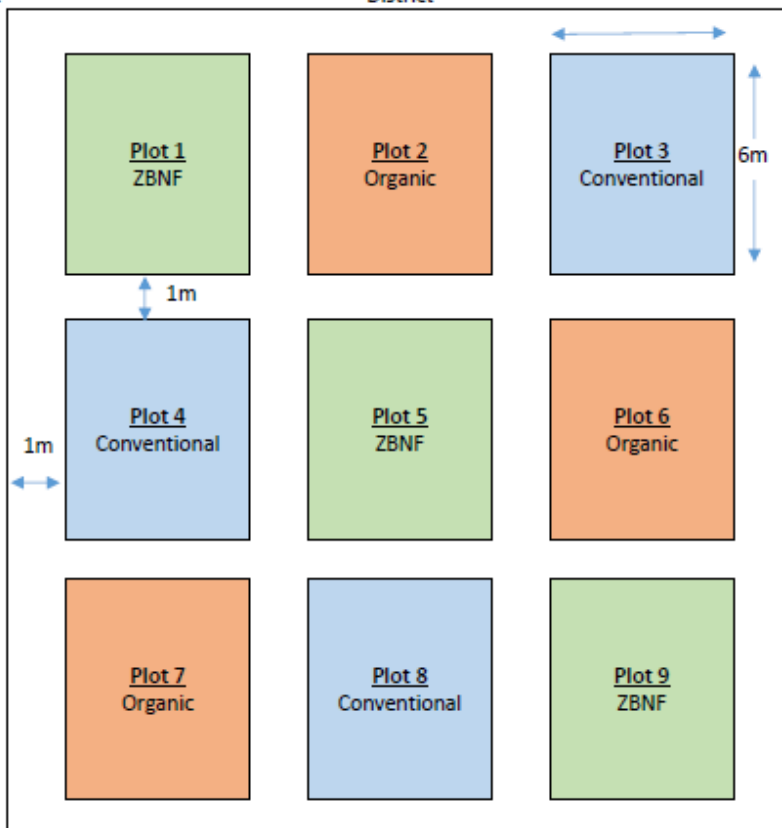
Note: it is important you stick to the plot arrangement on the next page that is in your booklet, each NFF in your region will have a different arrangement so do not copy someone else's experiment. If you lose your booklet ask your research coordinator or Sarah to send you another copy



Farm Reference

District

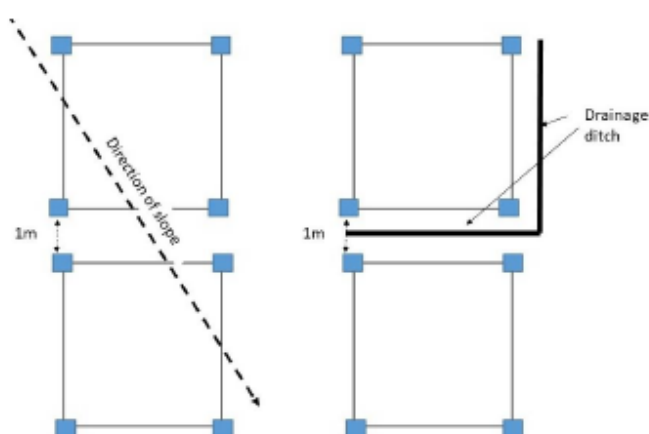
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19. It's important you know which plot is which, for the whole experiment. So sketch out your plots in this booklet (page 10) with features around them, so you remember which one is which.

20. Before you start adding your treatments to the plots or sow your crops some initial sampling and assessment is needed (see page 11 onwards)

If your plots are on a slope you may also consider adding drainage ditches in the middle of the path between the plots. Your research coordinator can advise you on this.





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3 Initial site description

Before we start, we'd like to know a little about your farm and, more specifically, the areas where you have put the experimental plots. We have provided a form for you to fill in and send a copy to Sarah:

Site Description

Date: _____

Latitude: _____

Agro climatic zone: _____

Longitude: _____

Farm: _____

Elevation (m): _____

Size of Farm (acres): _____

Landform designation:

- ☐ Medium gradient mountain
- ☐ Medium gradient hill
- ☐ Medium gradient escarpment
- ☐ Ridges
- ☐ Mountainous highland

- ☐ Dissected plain
- ☐ High gradient mountain
- ☐ High gradient hill
- ☐ High gradient escarpment
- ☐ Valley

- ☐ Major depression
- ☐ Narrow plateau
- ☐ Plain
- ☐ Low gradient mountain
- ☐ Low gradient hill

Location of plots

Are the plots on a slope (if so make direction of slope on your plot sketch)? _____

How long has this site been cultivated (years)? _____

What crop has been cultivated (with years)? If you can please provide the name of the crop cultivar and source of seeds (seed supplier or kept from previous harvest?) _____

Has ZBNF been practised on the land? _____

If so, how long has ZBNF been practised on this site (years)? _____

How was this area managed before ZBNF? _____

What proportion of your farm do you practise ZBNF already? _____

Do you plan to expand ZBNF to other crops in the next growing season? _____



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Plot Sketch include orientation, distances, direction of slope, any features (trees, streams, gates etc.)

Farm:

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4 Treatments

Once all initial assessment has been completed you can start with your treatments, but we need to know some details about how you manage your experimental plots:

ZBNF plots

Do you apply jeevamrutham to your crop on these plots? _____

Is the application of jeevamrutham soil, foliar or both? _____

Do you apply botanical extracts to your crop on these plots? _____

Do you apply ghanajeevamrutham to your crop on these plots? _____

Do you apply mulching to your crop? _____

Is the mulching live or dead? _____

Do you treat the seeds before planting? _____

Organic plots

Give a description of how these plots are managed (inputs, tillage etc.)

Conventional plots

Give a description of how these plots are managed (inputs, fertilizers, pesticides, tillage etc.)

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5 Crop Sowing

This experiment is a monocrop experiment

It is important that the same number of seeds are sown/ crops transplanted on each plot and they are spread evenly across the whole plot,

Also be sure if you irrigate/ water the crops, all plots must get the same

Example of plot experiment, same number of plants on each plot, evenly spaced



What crop have you sown on the plots (including genotype/ cultivar)? _____

Date sown: _____

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6 Yield measurements

At harvest we ask that you keep the harvests of each plot separate (even plots of the same treatment) so you will have 9 piles of harvest. A good way to keep them separate is to have a different tarpaulin (large sheet) for each plot and load the harvest directly onto the sheet.



Example of harvest from a single plot being loaded onto one sheet

Full plot measurements you will be taking will be:

Aubergine, Chilli, Okra or Tomato

- Total mass of plant biomass taken off each plot
- Total mass of fruits harvested from each plot

Clusterbean

- Total mass of plant biomass taken off each plot
- Total mass of pods harvested from each plot

Groundnut

- Total mass of plant biomass taken off each plot
- Total mass of pods harvested from each plot
- Total mass of kernels harvested from each plot

Radish

- Total mass of plant biomass taken off each plot

Figure S2 - Residual plots of REML mixed effects model on z transformed yield (treatment, district and crop variety as factors)

