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Principal Component Analysis for Yield in Blackgram (*Vigna mungo* L. Hepper) under Organic and Inorganic Fertilizer Managements

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Authors' contributions

This work was carried out in collaboration among all authors. Authors AKR and MSP designed the study. Author AKR performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation on thirty black gram diverse genotypes for 12 yield and yield attributing traits under organic and inorganic fertilizer managements was carried out to study genetic variation among traits and genotypes in the respective environments that would equip the selection criteria using principal Component Analysis. First four vectors with threshold Eigen value greater than one (>1) contributed to 77.56% and 70.74% variation under organic and inorganic fertilizer managements respectively. Characters *viz.,* number of clusters per plant (0.395), number of seeds per pod (0.354), days to maturity (0.336), number of pods per plant (0.300), harvest index (0.244), plant height (0.073) and seed yield per plant (0.015), whereas under inorganic fertilizer

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management number of primary branches per plant (0.43), followed by number of pods per plant (0.43), seed yield per plant (0.31), number of pods per cluster (0.29), number of clusters per plant (0.29) explained the maximum variance in first principal component (PC1) under organic conditions. Based on comparison of trait contribution to total variability under PC1 under both the managements it can be concluded that the traits *viz.,* number of clusters per plant, number of pods per plant and seed yield per plant were the potential traits that accounted for maximum share towards variability. These traits may be taken into consideration as selection criteria in breeding programmes aimed at developing high yielding varieties.

Keywords: Blackgram; principal component analysis; yield; organic fertilizer management; inorganic fertilizer management.

1. INTRODUCTION

Blackgram [*Vigna mungo* (L.) Hepper] (2n=22) is one of the most widely grown pulse crops, that occupies predominant role in conferring nutritional security of India, where majority of population rely on vegetarian sources to meet their nutritional requirements. Blackgram contains approximately 22-25% protein, 3.5% - 4.5% fiber, 4.5-5.5% ash and 60-65% carbohydrates on dry weight basis. Apart from good digestibility, blackgram also offers high quality dietary protein and a good portion of vitamins, iron and phosphorus. Blackgram cultivation in India is spread in an area of 5.60 M ha, production of 3.06 M t and productivity of 546 kg ha^{-1} [1]. Andhra Pradesh is one of the leading blackgram growing states of India with an area of 3.81 lakh hectares, production of 3.13 lakh tonnes and productivity of 821.5 kg ha^{-1} [1].

Although India occupies first place globally in terms of area and production of pulses, it is not yet self-sufficient and remains as net importer of pulses. Moreover, there is a decline in per capita availability of pulses from 60.7 g day^{-1} in 1951 to 56.0 g day^{-1} in 2019-20 as against the WHO's recommendation of 80 g day^{-1}. Therefore, to fulfill the protein requirement demands of the ever-rising population and to address the world malnutrition and hunger problems, pulses production needs to be boosted up. The only solution to address all these issues is development of stable high yielding varieties. Because of its polygenic nature and low heritability, direct selection for yield is not possible.

Yield is a dependant trait, which depends on several independent attributing traits. Hence developing selection criteria with potential yield attributing traits that would result in yield enhancement would be of research importance. In the present scenario of global climate change and increased awareness on hazardous impact of usage of large amounts of chemicals in agriculture, there is a major shift towards organic plant based foods. This opens a new avenue in plant breeding called organic breeding. The next challenge to the breeder is to develop cultivars that can thrive well under organic management conditions. The selection criterion which is normally applied do not fit well for every environment that highlights the need to evaluate genotypes under organic management before going for a plant breeding program. Hence the present study was targeted to evaluate diverse black gram lines under organic and inorganic fertilizer managements to decide upon the traits for yield enhancement under the respective environments. Principal component analysis is a technique required to identify and prioritize the important traits by minimizing the number of traits for effective selection and genetic gain. It identifies the minimum number of traits, which contributes maximum variability and also ranks genotypes on the basis of PC scores.

2. MATERIALS AND METHODS

The present investigation was carried out with 30 blackgram genotypes during Kharif, 2017 at dry land farm of Sri Venkateswara Agricultural College, Tirupati using a Randomized Block Design with three replications in each of the two experimental plots (Organic plot – Fig. 3; Inorganic plot – Fig. 4). The list of genotypes evaluated in the present study is presented in the Table 1.

2.1 Crop Management in Organic Plot

FYM was applied @ of 20 t ha^{-1} at the time of field preparation. *Jeevamrutha* @ 500 L ha^{-1} (Appendix A) was applied at 15 days interval from 20 days after sowing (DAS). Seed treatment was done with 3% *panchagavya* (Appendix B) and it was again sprayed at 25 and 35 DAS. For control of sucking pests, *bramhasthram* @ 2.5 % (Appendix C) was sprayed. No inorganic chemicals were applied in organic plot.

2.2 Crop Management in Inorganic Plot

Recommended dose of chemical fertilizers (20 kg N, 50 kg P_2O_5 per hectare) in the form of urea and single super phosphate were applied before sowing. Seed treatment was done with Bavistin @ of 3 g kg^{-1}. For the control of leaf eating caterpillars, chlorpyriphos @ of 2.5 ml L^{-1} and for the control of sucking pests monocrotophos @ of 1.6 ml L^{-1} was applied.

Cultural practices like weeding and irrigation were followed to maintain good crop growth in both the plots. Observations were recorded on five randomly taken plants in each genotype for plant height, number of primary branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, pod length, number of seeds per pod, 100 seed weight, harvest index, and seed yield per plant, whereas for days to 50 % flowering and days to maturity observations were recorded on plot basis.

The data was subjected to principal component analysis using the software WINDOWSTAT 9.2 version as per the procedure outlined by Rao [2].

3. RESULTS AND DISCUSSION

Principal component analysis for various yield contributing traits was done to evaluate diversity and some quantitative traits which had more effects on diversity. The Eigen value, per cent variance and percent cumulative variance for five principal components (PCs) and factor loading between PCs and traits studied in blackgram under organic and inorganic fertilizer managements are presented in Table 2 and Table 3, respectively.

The results of PCA under both the conditions revealed the genetic diversity of the 30 genotypes under study. Five principal components (PC1 to PC5) were extracted from the original data accounting for 84.50% and 77.56 % of the total variation under organic and inorganic fertilizer managements respectively. This suggests that these five principal component scores might be used to review the original eleven variables in any further analysis.
Out of total principal components maintained under organic fertilizer management PC1, PC2, PC3, PC4 and PC5 with values 30.10%, 19.01%, 16.63%, 11.80% and 6.94% (Table 2) respectively contributed more to the total variation. Under inorganic fertilizer management, the values of PC1, PC2, PC3, PC4 and PC5 were 29.63%, 18.83%, 12.26%, 10.00% and 7.64% (Table 3) respectively. In both the cases, the first four components attributed to more than 70% of variation. Similar reports were noted by Priya et al. [3], Mohanlal et al. [4], Sridhar et al. [5].

Table 1. List of 30 blackgram genotypes and their source

S. No.	Genotype	Source
1	KDRS-136	ARS, Madira
2	KU-10-1169	ARS, Madira
3	KU-10-1170	ARS, Madira
4	KU-11-685	ARS, Madira
5	KU-12-56	ARS, Madira
6	KU-14-01	ARS, Madira
7	KU-14-39	ARS, Madira
8	KU-14-47	ARS, Madira
9	LBG-752	Lam, Guntur
10	LBG-787	Lam, Guntur
11	LOP-1070	Lam, Guntur
12	MBG-1045	ARS, Madira
13	MBG-1050	ARS, Madira
14	NDU-11-201	ARS, Madira
15	P-1032	ARS, Madira
16	P-112	ARS, Madira
17	P-728	ARS, Madira
18	PU-205	ARS, Madira
19	PU-31	ARS, Madira
20	RFU-13-04	ARS, Madira
21	SU-13-08	ARS, Madira
22	SU-13-509	ARS, Madira
23	TBG-104	RARS, Tirupati
24	TU-94-02	ARS, Madira
25	UG-708	ARS, Madira
26	VVG-09-005	ARS, Madira
27	VBG-11-031	ARS, Madira
28	VBN-4	ARS, Madira
29	VBN-7	ARS, Madira
30	WBG-26	ARS, Madira

The first principal component contributed maximum towards variability (30.10%) under organic conditions. Characters *viz.,* number of clusters per plant (0.395), number of seeds per pod (0.354), days to maturity (0.336) and number of pods per plant (0.300), harvest index (0.244), plant height (0.073) and seed yield per plant (0.015) explained the maximum variance in first principal component (PC1). Whereas, under inorganic fertilizer management, number of primary branches per plant (0.43), followed by number of pods per plant (0.43), seed yield per plant (0.31), number of pods per cluster (0.29), number of clusters per plant (0.29) attributed to maximum variability for PC1. The respective traits in each environment may be given more importance while selecting high yielding genotypes.

A comparison of trait contribution to total variability for PC1 under both the managements out listed the traits number of clusters per plant, number of pods per plant and seed yield per plant as the potential traits.

The second principal component (PC2), which described 19.01 per cent of the total variance under organic conditions reflected significant loadings of days to maturity (0.46), number of primary branches per plant (0.33), seed yield per plant (0.015), harvest index (0.146), number of clusters per plant (0.13) and number of seeds per pod (0.12).

The second principal component (PC2), which described 18.83 per cent of the total variance under inorganic fertilizer management reflected significant loadings of pod length (0.47), number of seeds per pod (0.38), number of clusters per plant (0.36), days to maturity (0.34), seed yield per plant (0.30) and plant height (0.28).

Table 2. The Eigen value, per cent variance and percent cumulative variance for five principal components (PCs) and factor loading between PCs and traits studied in blackgram under organic fertilizer management.

	1 Vector	2 Vector	3 Vector	4 Vector	5 Vector
Eigene Value (Root)	3.61312	2.28222	1.99568	1.41654	0.83303
% Var. Exp.	30.10937	19.01854	16.63070	11.80450	6.94189
Cum. Var. Exp.	30.10937	49.12790	65.75861	77.56310	84.50499
Seed yield per plant	0.01534	0.15207	0.48351	0.42080	0.26980
Number of pods per plant	0.30076	-0.43124	0.18294	0.20000	-0.03141
Number of clusters per plant	0.39520	-0.32826	0.18750	0.05086	-0.08892
Number of pods per cluster	-0.38563	0.12950	0.19425	0.41383	0.05470
Number of seeds per pod	0.35404	0.11687	0.01303	0.15232	-0.62313
100 seed weight	-0.20277	-0.50731	-0.05362	0.33775	-0.12996
Harvest index	0.24432	0.14565	-0.29678	0.46794	0.33862
Pod length	-0.31063	-0.04343	-0.29968	-0.01517	-0.37239
Plant height	0.07288	-0.22810	0.47721	-0.40356	0.11489
Number of primary branches per plant	-0.08609	0.32929	0.41391	0.16858	-0.48450
Days to flowering	-0.39498	-0.01013	0.27970	-0.17786	0.04956
Days to maturity	0.33622	0.46010	0.04055	-0.17230	0.07999

Table 3. The Eigen value, per cent variance and percent cumulative variance for five principal components (PCs) and factor loading between PCs and traits studied in blackgram under inorganic fertilizer management

	1 Vector	2 Vector	3 Vector	4 Vector	5 Vector
Eigene Value (Root)	3.55630	2.26014	1.47224	1.20075	0.91692
% Var. Exp.	29.63582	18.83446	12.26863	10.00623	7.64101
Cum. Var. Exp.	29.63582	48.47028	60.73891	70.74514	78.38615
Seed yield per plant	0.31326	0.30259	0.04268	0.18670	0.18924
Number of pods per plant	0.43073	0.25759	-0.07077	-0.11530	-0.30756
Number of clusters per plant	0.29873	0.36344	-0.26217	-0.16006	-0.40968
Number of pods per cluster	0.29989	-0.22738	0.42158	-0.10767	-0.06632
Number of seeds per pod	-0.06755	0.38342	0.30100	0.30306	0.28459
100 seed weight	-0.06766	0.21151	0.64134	0.15765	-0.41530
Harvest index	-0.21109	-0.11300	-0.35938	0.49596	-0.48037
Pod length	-0.10803	0.47141	-0.23946	0.25829	0.33828
Plant height	-0.22766	0.28477	0.06913	-0.54260	0.07746
Number of primary branches per plant	0.43390	-0.15601	-0.20469	-0.16793	0.22983
Days to flowering	-0.42246	-0.07936	-0.02718	-0.27561	-0.03369
Days to maturity	-0.23070	0.34616	-0.10433	-0.29439	-0.19685

The third principal component (PC3) was categorized clearly by high loading of seed yield per plant (0.483) followed by positive plant height (0.477), number of primary branches per plant (0.414), days to flowering (0.279) and number of pods per cluster (0.194) under organic conditions. The third principal component (PC3) was categorized clearly by high loading of 100 seed weight (0.64) followed by positive number of pods per cluster (0.42), number of seeds per pod (0.30), plant height (0.06) and seed yield per plant (0.04) under inorganic conditions. Plant height and number of pods per cluster are the traits affording high variability for this component in common for both the managements.

Table 4. The PCA scores of genotypes of thirty blackgram genotypes under organic fertilizer management

	PCA I	PCA II	PCA III
Genotypes	X Vector	Y Vector	Z Vector
KDRS-136	-11.232	-6.816	5.906
KU-10-1169	-10.528	-5.265	4.089
KU-10-1170	-15.129	-9.471	1.640
KU-11-685	-12.900	-4.002	6.683
KU-12-56	-8.215	-1.812	6.489
KU-14-01	-10.703	-12.388	3.559
KU-14-39	-6.610	-3.795	4.107
KU-14-47	-8.313	-4.331	3.264
LBG-752	-14.948	-5.654	5.831
LBG-787	-13.442	-9.328	4.263
LOP-1070	-11.506	-8.809	3.602
MBG-1045	-13.729	-6.449	3.886
MBG-1050	-12.046	-9.206	4.806
NDU-11-201	-12.626	-4.644	4.648
P-1032	-11.074	-2.610	2.699
P-112	-5.784	-7.565	7.136
P-728	-10.954	-5.762	2.418
PU-205	-9.044	-2.764	3.954
PU-31	-9.139	-1.823	5.296
RFU-13-04	-9.593	-3.629	7.341
SU-13-08	-14.399	-5.158	2.713
SU-13-509	-12.068	-3.326	1.979
TBG-104	-9.175	-4.912	4.871
TU-94-02	-13.663	-8.985	5.098
UG-708	-12.087	-4.721	4.579
VBG-09-005	-12.401	-4.936	3.045
VBG-11031	-11.232	-2.068	3.247
VBN-4	-11.007	-1.544	4.429
VBN-7	-11.382	-1.890	2.049
WBG-26	-10.012	-5.344	4.945

The PCA scores for 30 genotypes in the first three principal components under organic and inorganic fertilizer managements were computed and presented in Tables 4 and 5, respectively. The PCA scores for 30 genotypes were plotted in graph to get the 3D (PCA I as X axis and PCA II as Y axis) scatter diagram as presented in Fig. 1 (organic management) and Fig. 2 (inorganic management) respectively.

Table 5. The PCA scores of thirty blackgram genotypes under inorganic fertilizer management

	PCA I	PCA II	PCA III
Genotype	X Vector	Y Vector	Z Vector
KDRS-136	-14.172	22.258	3.600
KU-10-1169	-15.465	21.490	2.257
KU-10-1170	-15.268	23.586	2.961
KU-11-685	-14.016	20.454	3.223
KU-12-56	-13.908	22.428	3.197
KU-14-01	-15.098	19.099	3.034
KU-14-39	-14.154	22.060	2.416
KU-14-47	-14.714	20.695	4.203
LBG-752	-15.064	18.375	4.258
LBG-787	-14.755	21.041	2.386
LOP-1070	-14.694	19.275	2.712
MBG-1045	-13.775	21.130	2.762
MBG-1050	-15.401	22.331	1.562
NDU-11-201	-14.103	22.027	2.559
P-1032	-13.117	20.672	2.028
P-112	-10.053	21.179	1.359
P-728	-15.515	20.285	2.259
PU-205	-12.624	21.428	1.708
PU-31	-11.874	19.928	2.833
RFU-13-04	-15.628	20.256	1.380
SU-13-08	-10.193	20.337	3.906
SU-13-509	-14.325	21.815	2.474
TBG-104	-12.501	23.389	2.072
TU-94-02	-11.592	20.922	2.035
UG-708	-10.208	23.022	2.271
VBG-09-005	-13.977	20.556	2.945
VBG-11031	-13.381	22.461	4.484
VBN-4	-12.273	21.802	1.351
VBN-7	-8.505	20.307	2.266
WBG-26	-11.587	22.292	2.997

None of the genotypes had positive values for PC1 and PC2 under organic conditions, whereas PC1 registered all negative values under inorganic fertilizer management. RFU-13-04 (7.34) had the highest value for PC3 followed by P-112 (7.13), KU-11-685 (6.68), KU-12-56 (6.48), KDRS-136 (5.90) indicating that these genotypes are better performers for the traits that weighed high values in PC3 i.e., seed yield per plant (0.483) plant height (0.477), number of primary branches per plant (0.414), days to flowering (0.279) and number of pods per cluster (0.194) for PC3 under organic fertilizer management.

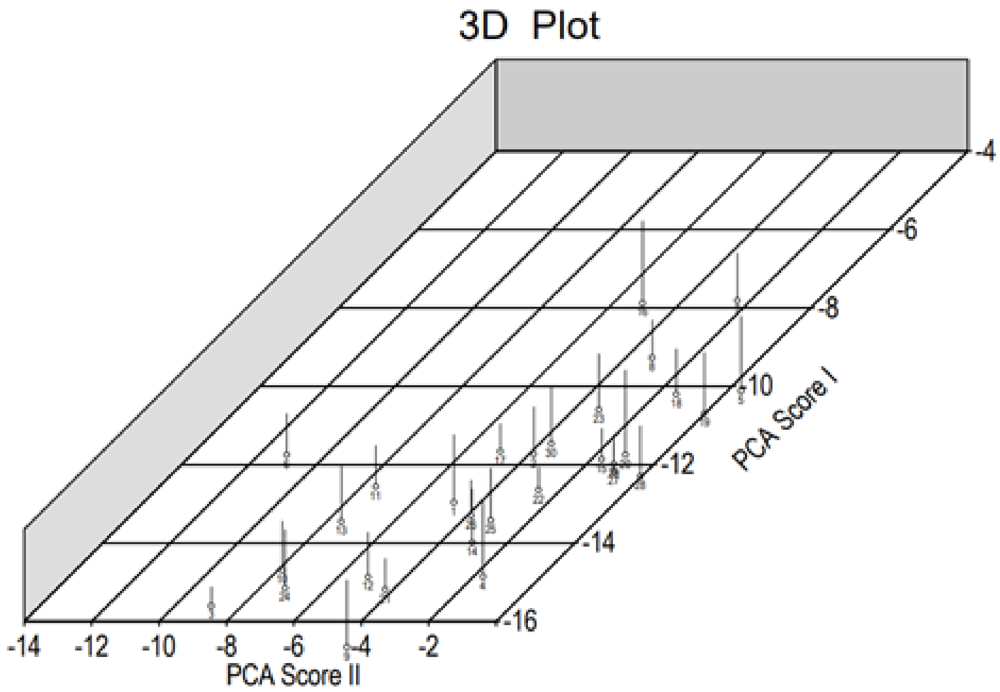

Fig. 1. 3D plot under organic fertilizer management

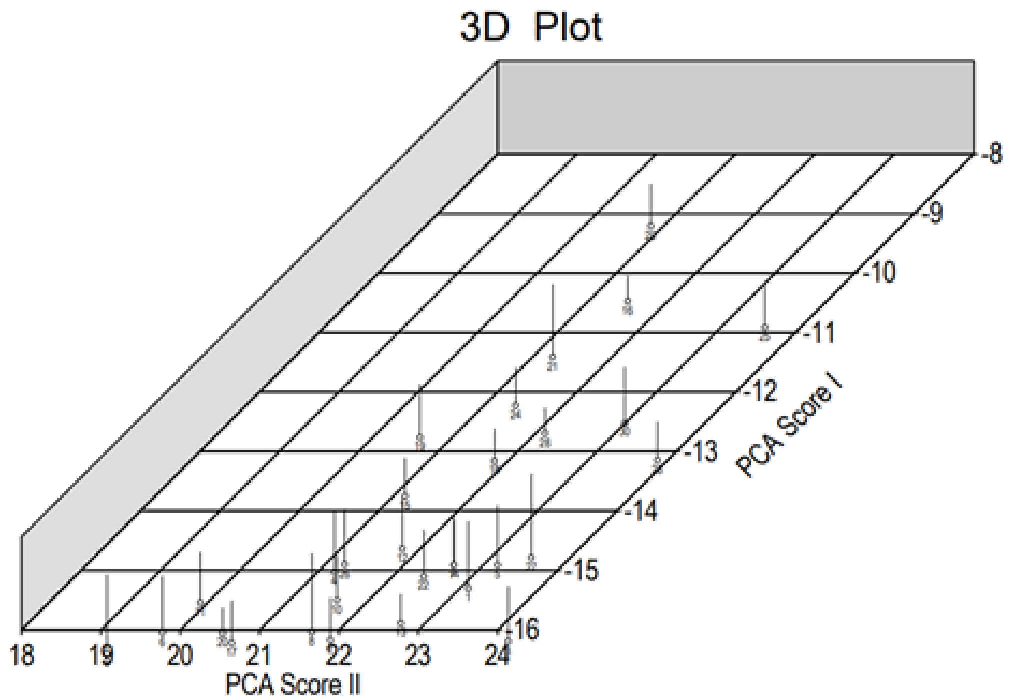

Fig. 2. 3D plot under inorganic fertilizer management

Top five lines that noted high values for PC2 under inorganic fertilizer management are KU-10-1170 (23.78), TBG-104 (23.38), UG-708 (23.02), VBG-11031 (22.46) and KU-12-56 (22.42). For PC3 the superior lines are VBG-11031 (4.48), LBG-752 (4.25), KU-14-47 (4.20), SU-13-08 (3.90) and KDRS-136 (3.60).

Fig. 3. Field view of organic plot

Fig. 4. Field view of inorganic plot

4. CONCLUSION

Differential results under both the managements signifies that the performance of genotypes and the selection criteria is highly variable across environments, highlighting the need to evaluate genotypes and develop location specific selection criteria which is of profound importance in plant breeding.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Appendix A

JEEVAMRUTHA PREPARATION

Materials required:

- Water – 200 litres
- Cow dung – 10 kg (Indigenious Cows, Preferably)
- Cow urine – 5 litres (Indigenious Cows, Preferably)
- Jaggery – 2 kg
- Flour of any pulse – 2 kg
- Soil from same land – one handfull.

Preparation process:

First of all, 200 litres of water was taken in the drum and then other ingredients were added to it. The contents were mixed well and the drum was kept under shade, covered with wet gunny bag and incubated for 4-5 days. The mixture was stirred in clockwise direction once a day.

Appendix B

PANCHAGAVYA PREPARATION

7 kg of cow dung and I kg of cow ghee were mixed in a wide mouthed plastic can and the container was kept under shade. The container was kept covered with a plastic mosquito net to prevent houseflies from laying eggs. It was mixed thoroughly both in morning and evening hours for three days. After three days, 10 litres of cow urine and 10 litres of water was added to the mixture. It was kept for 15 days with regular stirring both in the morning and evening hours. After 15 days, 3 litres of cow milk, 2 litres of cow curd, 3 litres of tender coconut water, 3 kg of jaggery and 12 nos. of well ripened banana were added. All the contents were stirred twice a day both in morning and evening. The panchagavya stock solution was ready after 30 days.

Appendix C

BRAMHASTHRAM PREPARATION

Materials required:

Cow urine – 10 litres (Indigenious Cows, Preferably)
Neem leaves – 3 kg
Sitaphal leaves – 2 kg
Papaya leaves - 2 kg
Pomegranate leaves - 2 kg
Guava leaves – 2 kg
White datura leaves – 2 kg

Preparation process:

All the leaves were grinded into paste and boiled in 10 litres of cow urine. The mixture was cooled, filtered using cloth and allowed to ferment for 24 h. the stock solution will be ready after 24 h.

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