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EXPLOITING WILD SPECIES AS SOURCE OF RESISTANCE AGAINST MAJOR PESTS AND DISEASES IN GROUNDNUT

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ABSTRACT
A field experiment was laid out at Regional Research Station, Vridhachalamduring 2020 with the already existing thirty numbers of groundnut wild species to explore and identify the resistance sources against major pests like leaf hopper Empoasca kerri, groundnut leaf miner, Aproaerema modicella and Spodoptera litura and diseases viz., leaf spots, rust, stem rot and root rot.Four observations were made at monthly intervals from the date of sowing in each season.Percent leaf damage by hopper,leaf miner,Spodoptera, percent disease incidence were observed and categorised as resistance or susceptible. A.villosa recorded 3.09% leaf hopper damage followed by A.helodes 3.55% are categorized as resistant to leaf hopper.A.villosa and A.helodes recorded late leaf spot and rust disease score of 1.A.villosa recoded 2.95%Stem rot and 2.2% root rot incidence.Specific leaf weight was minimum in A.cardenasii(8216) (0.01 mg/cm^2) and maximum was recorded in A.hermannii(13251)(0.12 mg/cm^2).A.villosa (8144) recorded maximum abaxil surface trichome density of 53.33/0.25cm^{2}and minimum in VRI 2 27.33 trichomes per 0.25cm^2. Higher total phenol contents were observed in A.helodes (694.72mg/100g) followed by VRI-2(689.59mg/100g) but total tannin content was high in A.villosa(873.2mg/100g) followed by VRI -2(800.31mg/100g).Low total sugar content was observed in A.villosa(3.29%) followed by VRI-2(4.96%). Reducing sugar was less in A.villosa (0.70%) and non reducing sugars in A.helodes(1.70%).

KEYWORDS: groundnut; leaf hopper; leaf miner; resistance; wild species

INTRODUCTION
Groundnut (Arachis hypogaea L.) is one of the important oilseed crops cultivated in India during kharif, rabi and summer seasons. Gujarat, Andhra Pradesh, Tamil Nadu, Rajasthan, Karnataka and Maharashtra are the major groundnut growing states of India and together account for about 90% of the national area under groundnut.Pests and diseases are one among the major factors in limiting the groundnut production. More than 360 species of insects and mites are known to be the pests attacking the groundnut (1). Besides that many serious fungal and viral diseases are also infecting the crop including root rot, stem rot, leaf spot, leaf blight, rust, bud necrosis virus, tomato spotted wilt virus etc. The defoliators Spodoptera litura (Fab.), Aproaerema modicella, soil dwellers white grubs, termites, wireworms, and earwigs are responsible for yield reduction (2). Severe outbreak of the pest results in 30-40% loss in pod formation (3). Early leaf spot (ELS) (Cercosporaarachidicola), late leaf spot (LLS) (Cercosporidium personatum), rust (Puccinia arachidicola), root rot (Macrophomina phaseolina), stem rot (Sclerotium rolfsii) are the major foliar fungal diseases of groundnut. Indiscriminate use of pesticides and fungicides forthe management of various pests and diseases lead to pesticide resistance, pest resurgence, secondary pest outbreaks, destruction of beneficial insects and other natural fauna, accumulation of undesirable residues resulting in environmental pollution and severe health hazards. At present, no cultivated groundnut species express resistance againstmajor insect pest and diseases. Few wild groundnut species are having resistance to S.litura (4). Resistance sources from groundnut wild relatives will be greatly useful for breeding programme to develop varieties showing broad resistance to both damaging pests and diseases. With the purpose of exploring the resistance sources among groundnut wild species, this current experiment has been designed and executed.

Materials and methods
A field experiment was laid out at Regional Research Station, Vridhachalam during 2020 with the already existing thirty numbers of groundnut wild species (Table 1.) to explore and identify the resistance sources against major pests like leaf hopper Empoasca kerri, groundnut leaf miner, Aproaeremamodicella and Spodoptera litura and diseases viz., leaf spots, rust, stem rot and root rot.
The wild species of groundnut were screened for the identification of resistance against major pests and diseases. Four observations were made at monthly intervals from the date of sowing in each season. Percent leaf hopper damage was observed in the form of yellowing on apical end of leaflets in a typical “v” shaped necrotic patch also known as hopper burn. Percent defoliation by tobacco cut worm were observed and injury rating 1-9 scale followed. Percent leaf damage byleaf minerwas observed and injury rating 1-9 scale worked out.

Resistance scale for Leaf hoppers

Yellowed foliage (%)	Injury rating	Category of resistance
0	1	Highly Resistant
1-5	2	Resistant
6-10	3	Moderately resistant
11-20	4	Moderately Susceptible
21-30	5	Susceptible
31-40	6	Highly Susceptible
41-50	7	Highly Susceptible
51-75	8	Highly Susceptible
76-100	9	Highly Susceptible

Resistance scale for defoliators

Leafminer			**Spodoptera and Helicoverpa**		
Leaflets damaged (%)	**Injury rating**	**Category of resistance**	**Defoliation (%)**	**Injury rating**	**Category of resistance**
0	1	Highly resistant	0	1	Highly Resistant
1-25%	3	Resistant	1-5	2	Resistant
26-50%	5	Moderately resistant	6-10	3	Moderately resistant
51-75%	7	Susceptible	11-20	4	Moderately Susceptible
76-100% or death of plant	9	Highly Susceptible	21-30	5	Susceptible
			31-40	6	Highly Susceptible
			41-50	7	Highly Susceptible
			51-75	8	Highly Susceptible
			76-100	9	Highly Susceptible

Late leaf spot (LLS) and rust diseases incidenceswere observed using 1-9 scale of disease score and stem rot and root rot incidence were observed and expressed in terms of percent disease incidences (AICRP on Groundnut proceedings 2020). Observations were made both during the years 2020-2021 and 2021-2022.

Biophysical parameterslike, the specific leaf weight (SLW) indicates the leaf thickness was calculated(5)and expressed as g cm^{-2}.

$$SLW = \frac{\text{Leaf dry weight (g)}}{\text{Leaf area (cm}^2\text{)}}$$

Relative water content was estimated and expressed as percentage (6). Leaf discs were prepared and fresh leaf weight (g) was measured. Then discs are immersed in water for 4 hours to absorb water and later, discs are taken out and turgid leaf discs are weighed and expressed as turgid leaf weight (g). After that, discs are taken and kept in oven for 48 hours at 70° C for drying. Later, disc weight will be taken and expressed as dry weight (g).

$$\text{Relative Water Content (\%)} = \frac{\text{(Fresh weight - Dry weight)}}{\text{(Turgid weight - Dry weight)}} \times 100$$

Trichome density leaf lamina was analyzed by following the procedure (7). Five fully developed leaves from each genotype was heated with 20 ml of distilled water in a test tube for five minutes in an waterbath at 85°C. After five minutes, water of test tube was decanted and added with 20 ml of 96 per cent ethyl alcohol and the samples were heated again for 10 minutes at 80 °C. The alcohol was decanted and the same procedure was repeated 3 times and the chlorophyll content was removed. Finally, 20 ml of 90 per cent concentrated lactic acid will be added and heated again at 85 °C for 45 minutes. Test tubes were cooled and stored for further observation. Leaf bits were mounted on glass slide and observed trichomes under stereo zoombinocular microscope (micros) at 10X on 0.25 cm^2 area of under surface leaf (abaxial surface). Leaf area was calculated by length and width method (8). SPAD chlorophyll meter reading was taken for relative amount of chlorophyll (Minolta company, NJ, US SPAD 502).

Based on the results of field studies and bio physical studies the promising wild species showing resistance was determined the biochemical parameters. Biochemical components were analyzed at Post Harvest Technology Centre, Tamil Nadu Agricultural University, Coimbatore. Carbohydrates and protein content were analysed by IS 1656:2006 and kjeldahl method respectively. Total phenols, total tannins, total sugars, reducing sugars and non reducing sugars were analysed (9).

RESULTS

Sucking and chewing insects incidence during 2020-2021

Results revealed that leaf hopper damage ranged from 2.72% to 19.21%. Arachis villosa (2.72%) and Arachis helodes (3.41%) recorded less than 5% leaf damage. Six wild sp recorded less than 10% leaf damage but more than 5 % leaf damage (Arachis villouslicara (7.03%), Arachis appressipilla (8.46%), Arachis marginata (8.38%), Arachis correntina (8.60%), Arachis paraguariensis (9.19%), Arachis hermannii (9.21%)). Based on injury rating A.villosa (8144) was recorded 1.8 grade followed by A.helodes (8915) recorded 2.0 grade and falls in the resistant category. Eighteen wild species falls in moderately resistant category and rest of the wild species falls in moderately susceptible category and VRI 2 falls in susceptible category (Table 2.).

Groundnut leaf miner damage was ranged from 1.01 to 4.82%. Arachis villosa(1.01%), Arachis posilla (1.59%), Arachis paraguariensis (1.98%) recorded less than 2% leaf damage. Fifteen wild species recorded more than 2% leaf damage but below 3%. Seven wild species recorded more than 3% but below 4% leaf damage. Four wild species recorded more than 4% leaf damage but below 5% leaf damage (A.correntina (4.28%), A.stenesperma (O) (4.34%), A.marginata (4.48%), A.diogoi (8962) (4.82%) while in VRI 2 recorded 16.25%. All the wild species falls under resistant category based on the injury rating.

S.litura leaf damge ranged in between 4.04 to 15.67%. Arachis helodes (4.04%), Arachis villosa(4.20%), Arachis villouslicara (4.64%), Arachis rigoni (4.97%) and Arachis batizocoi(4.80%) recorded below 5 % leaf damage which falls under resistant category. Remaining wild species falls under moderately resistant category. Arachis villosarecorded 1.04% leaf damage caused by H.armigera followed by Arachis correntina2.8%. A.monticola (ICG-11800) (3.38%), A.expansis (3.99%), A.batizocoi (3.56%), A. hermannii (13251) (3.30%) recorded less than 4% leaf damage. Nine wild species recoded more than 4% leaf damage but more than 5% leaf damage. Seventeen wild species falls under resistant category Based on the injury rating.

Disease incidence during 2020-2021

During the year 2020-21, A.villosa, A.helodes recorded disease score 1 followed by A.monticolawhich was recorded with scale 3. Eleven wild species recorded disease score 6 and nine species recorded disease score 7. Six wild species recorded disease score 8. A.hermanii and VRI 2 recorded disease score 9 (Table 3).

Rust incidence was minimum in A.villosa with the score of 1 A. cardenasii, A. kuhlmannis, A. helodes, A. stenosperma (HLK410), A. rigonii, A. appressipila, A. duransis, A. diagoi, A. rigoni (auto tettraploid ICG8186) followed by A. hermansis (13251) recorded disease score 3. Stem rot incidence was ranged in between 2.5 – 28.3%. minimum of 2.5% stem rot incidence was observed in A. helodes (8955) followed by 3.6% in A. villosa (8144), 6.4% in A. batizocoi (12018) and maximum in VRI 2 check of 28.3%. minimum root rot incidence was observed in A. villosa (8144) followed by 35% in A. helodes (8955) and 7.5 % in A. diogoi (8962) and maximum of 26.5% root rot incidence was observed in VRI 2 followed by 21.5% in A.duranensis (8202). The same trend was followed during the year 2021-2022 also as A. villosa and A. halodes were showing multiple resistance to the diseases late leaf spot, rust, stem rot and root rot.

Sucking and chewing insects incidence during 2021-2022

During 2021-2022, leaf hopper damage was maximum in A.stenosperma (HLK410)(19.46%) and minimum in A.villosa (8144)(3.47%) followed by A.helodes (8955)(3.69%). Seven wild species recorded below 10% leaf hopper damage but more than 7%. Based on the leaf hopper injury rating A.villosa (8144), A.helodes (8955) and A.appressipila (8129) falls under resistant category. A.stenosperma (HLK410), A.rigoni falls under moderately susceptible while VRI 2 falls under susceptible category. Other wild species were falls under moderately resistant category (Table 4).

Groundnut leaf miner damage was minimum in A.villosa (8144) (1.31%) followed by A.posilla(4897)(2.34%). All the wild species were falls in resistant category. Maximum spodoptera damage was recorded in A.stenosperma(O)(15.31%) and minimum in A.helodes(8955)(4.34%). Fourteen wild species recorded more than 5% Spodoptera damage but below 10%. Thirteen wild species found to be resistant against Spodoptera. A.marginata shows susceptibility towards Spodotera. Remaining wild species falls under moderately resistant category. Helicoverpa damage was ranged from 1.29% to 8.21%. Eighteen wild species falls under resistant category and other wild species falls under moderately resistant.

Disease incidence during 2021-2022

During the year 2021-22, A.villosa, A.helodes recorded disease score 1 for late leaf spot followed by A.monticola (4) and A.kempffmercadoi, A.pintoi, A.rigoni, A.duranansis recorded disease score 5. Seven entries recorded disease score 7 and seven entries score 8. For rust disease A.villosa and A.helodes recorded score 1 followed by A.apprassipilla (2). Seven entries recorded disease score of 3 and four entries recorded score of 4. Stem rot incidence was ranged inbetween 1.6% and 32.5%.A.helodes recorded 1.6% stemrot followed by A.villosa 2.3%,A.correntina 6.1%,A.kuhlmannis 8.3% rest of the entries recorded more than 10% and below 20% stem rot incidence. Root rot incidence was minimum in A.villosa (1.6%) followed by A.helodes (2.4%), A.pintoi and A.cruziana (8.5%) rest of the entries recorded more than 10% and below root rot incidence (Table 5).

Sucking and chewing insects incidence (2021-2022 &2021-2022)

Two years combined results revealed that,leaf hopper damage ranged from 3.09% to 40.76%. A.villosa recorded 3.09% leaf hopper damage followed by A.helodes 3.55% are categorized as resistant to leaf hopper. There are seven entries recorded more than5% leaf hopper damage but less than 10% which are considered as moderately resistant to leaf hopper.Another twenty entries recorded more than 10% but below 20% leaf damage which are categorized as moderately susceptible and check entry considered as highly susceptible. All the entries recorded less than 5% leaf miner damage are consider as resistant. A.villosa (4.35%), A.helodes (4.19%) and A.villouslicara (4.76%) are recorded less than 5% leaf damage by Spodoptera litura and categorized as resistant. Seventeen entries recorded less than 6% leaf damage by Helicoverpa armigera are categorized as resistant and fourteen entries more than 6% but below 10% leaf damage are considered as moderately resistant(Table 6).

Disease incidence (2020-2021&2021-2022)

Two years combined data revealed that A.villosa and A.helodes recorded late leaf spot disease score of 1 followed by A.duranensis (2.2), A.monticola (3.5). A.villosa recorded rust score 1 followed by A.helodes (1.5). Seven entries recodedrust score of 2.5 and two entries by 3.5 rust score. Stem rot incidence was minimum in A.helodes (2.05%) followed A.villosa(2.95%), A.correntina (6.65%), A.kuhlmannis (7.95%), A.batizocoi (9.35) rest of the entries scored more than 10% stem rot incidence. A.villosa recorded 2.2% root rot followed by A.helodes (2.95%), A.pintoi (8.05%), A.diogoi (9.4%) and A.botizocoi (9.85%) rest of the species recorded more than 10% root rot incidence (Table 7).

Biophysical characteristics

Leaf let area was ranged in between 1.06cm^2 – 4.53cm^2. A.hermannii recorded 1.06 sq cm leaf area followed by A.pintoi (1.59 sq cm), A.monticola (1.65 sq cm) and A.glabrata (1.80 sq cm). Six wild species had the leaf area of more than 4 sq cm but below 5 sq cm. More leaf let area was observed in A.posilla (4897) 4.53 sq cm followed by A.cardenasii (8216) 4.33 sq cm, A.duranensis (8202) 4.22 sq cm, A.rigoni (auto tetraploid ICG8186) 4.18 sq cm, A.cruziana (12984) 4.12 sq cm and A.kampff-mercadai 4.05 sq cm while in check VRI 2 it was 4.60 sq cm.

Relative water content was ranged in between 90.10% to 94.70%. Minimum relative water content was recorded in A.villosa (8144) (90.10%) followed by A.pintoi (90.30%), A.diogoi (8962)(90.90%) and maximum of 94.70% in VRI 2. Twelve wild species recorded more than 94% relative water content but below 95%. In eight wild species relative water content was ranged in between 92.1% - 93.9%.

SPAD meter reading (chlorophyll content) was minimum in A.hermannii (28.20), A.rigoni (29.80) and maximum of 44.30 in A.cardenasii followed by A.duranensis (41.10), A.kampff-mercadai (40.80). Rest of the entries recorded more than 31.00 but below 40.00.

Specific Leaf Weight was minimum in A.cardenasii (8216) (0.01 mg/cm^2) followed by A.kampff-mercadai, A.cruziana (12984), A.duranensis (8202), A.rigoni (auto tetraploid ICG8186) of 0.02 mg/cm^2 and maximum was recorded in A.hermannii(13251)(0.12 mg/cm^2).

A.villosa (8144) recorded maximum abaxil surface trichome density of 53.33/0.25cm^2 followed by A.appressipila (8124) 51.33, A.batizocoi (12018) 49.33 and A.stenosperma (O),A.rigoni, and VRI 2 recorded minimum of 27.33 trichomes per 0.25cm^2(Table 8).

Biochemical components

Earlier studies revealed that, Arachis villosa (3.09 %) and Arachis helodes(3.55%) recorded less than 5% leafhopper damage and falls under resistant category. A.villosa recorded 2.41% groundnut leafminer damage. Regarding defoliation, A. helodes and A.villosa recorded 4.19 and 4.35% Spodoptera litura leaf damage and A.villosa also recorded 1.16% leaf damage by Helicoverpa and falls under resistant category.Two years combined data revealed that A.villosa and A.helodes recorded late leaf spot disease score of 1.A.villosaand A.helodesrecorded rust score 1 and 1.5 respectively. Stem rot incidence was minimum in A.helodes (2.05%) followed A.villosa (2.95%).Root rot incidence was minimum in A.villosa(2.2%) and A.helodes (2.95%). The screening study finds that A.villosa and A.helodes shows multiple resistance against groundnut sucking pests like leaf hopper, defoliators like groundnut leaf miner, Spodoptera litura, Helicoverpa and groundnut diseases. In order to find the relationship between the biochemical components and pest and disease resistance, the prominent wild species A.villosa and A.helodes were subjected to biochemical analysis.

A.villosa recorded 28.82% carbohydrate followed by A.helodes 30.53% and VRI-2 (30.95%). Regarding protein profile, 16.60% recorded A.helodes followed by VRI-2(17.25%) and A.villosa (18.39%). Higher total phenol contents were observed in A.helodes (694.72mg/100g) followed by VRI-2(689.59mg/100g) but total tannin content was high in A.villosa (873.2mg/100g) followed by VRI -2(800.31mg/100g). Low total sugar content was observed in A.villosa(3.29%) followed by VRI-2(4.96%). Reducing sugar was less in A.villosa (0.70%) and non reducing sugars in A.helodes(1.70%)(Table 9).

DISCUSSION

Pest resistance

A.correntina, A.cardenasii, A.duranensis and A.villosa from Arachis section apart from erectoides, ambinervosae and rhizomatosae free from leaf hopper attack(1). Arachis accessions showed tolerancy against hopper by reducing the fecundity(10). A.villosa and A.burkartii were unsuitable hosts for S.frugiperda development(11). A.correntina, A.villosa, A.chacoense, A.stenosperma recorded 0.5 to 1.6% leaf damage by Heliothissp while in A.hypogea it was 37.0% (1). A.villosa, A.monticola, A.stenosperma, A.kamphmercadii, A.appresipila, A.glabrata, A.cardenasii, A.batizogaea, A.stenophylla were showed resistance againtS.litura(12). S.litura neonate larval mortality of 94% was observed in A.batizogaea, A.kemphmercadoi, A.appresipila, A.paraguariensis, A.stenophylla and A.villosa (12).

The germplasm line ICGV 86031 recorded 7.82% leaf damage by leaf miner than the susceptible line JCG 3341 (18.40%) (13). The germplasm. ICGV 16679 (13.71%), ICGV 07222(14.00%), ICGV93468(14.25%) (13) lines recorded less than 15.00% S.litura leaf damage. The entries K 1451, VG 9521, ICGV 94379, K 1736, VRI (GN 6), K 1661, TGLPS 03, K 1706 and K 1809 were had less than 15.00% leaf miner damage and considered as resistant and another 15 entries reported as moderately resistant against groundnut leaf miner(14) and out of 50 germplasm lines,15 lines were found to be resistant against Spodoptera litura (15).

Biophysical characteristics

The morphological character like leaf area, relative water content, specific leaf weight, chlorophyll content, trichome density imparts resistance against insect pests Higher leaf thickness and trichome density in resistant genotype k 1809 and other genotypes were ranged from 31.51 to 27.76 mm and 32.09 to 35.02 no.per 3 mm^2 than the susceptible check K 6 (20.33mm and 24.53 no./3mm^2) which showed positive correlation(14). Leaf thickness and trichome density imparts resistance against leaf miner in groundnut (16). Trichome density on leaf lamina was negatively correlated with leaf miner,Spodopteralitura damage(13,17,18,19) and groundnut bud borer damage (20).A.monticola recorded 45.7% relative water content while in resistant genotype ICG 928 had 54.2% which showed positive correlation with S.litura damage(17). Trichome density was ranged in between 25.68(K6) to 54.56(ICGV171015) in groundnut germplasm lines which negatively correlated with leafhopper population (22). Similar results were obtained from brinjal (23), Okra (24) and cotton (25).

The specific leaf weight was more than 2.5g/dm^2 in resistant genotypes ICG 928,ICG 76,ICG 4412,ICGV 93468 and wild species A.monticola showed negative correlation with Spodoptera litura damage (17). (21) Ramanaji Naralasetti and Katlam 2023 found the chlorophyll content was negatively correlated with thrips incidence in redgram (21) and groundnut (26).

Biochemicals characteristics

Leaf hopper population was significantlypositively correlatedwith total sugar and protein content (22) but negatively correlated with phenol and tannin contents. Higher phenols and tannins in cotton entries exhibited resistance to jassids (27). Higher levels of total phenols lower the thrips damage in groundnut germplasms (21,28,29,30). Total phenol content had a negative correlation with S.litura damage in groundnut (17, 32), soybean (31), pigeonpea (33). Total phenol content had a negative correlation with leaf miner damage in groundnut (13,14,18,19,34,35,36). The plant secondary metabolite phenol has a different role in affecting the biology of the insects. Total sugar and proteins have the positive correlation with the incidence of S.litura and leaf miner in groundnut germplasm lines (13,17). Reducing sugar, nonreducing sugar and total sugars in the groundnut varieties had the positive association with leaf miner incidence (14,19,34,37), thrips damage (21,29) and jassid damage (28).

CONCLUSION

The screening study found that A.villosa and A.helodes showed multiple resistance against groundnut sucking pests like leaf hopper, defoliators like groundnut leaf miner, Spodoptera litura, Helicoverpa and groundnut diseases.abaxil surface trichome density, total phenol,tannin contents contributed for resistance.

Table 1. List of wild species of groundnut

S.No	Wild species	S. No	Wild species
1	Arachis kempff-mercadoi	16	Arachis duranensis
2	Arachis botizocoi (8201)	17	Arachis expensis
3	Arachis villosa (8144)	18	Arachis monticola (8135)
4	Arachis cardenasii (8216)	19	Arachis glabrata
5	Arachis kuhlmannis	20	Arachis batizocoi(12018)
6	Arachis correntina	21	Arachis diogoi (8962)
7	Arachis helodes (8955)	22	Arachis duranensis (8202)
8	Arachis monticola (ICG-11800)	23	Arachis posilla (4897)
9	Arachis stenosperma (HLK410)	24	Arachis paraguariensis (8130)
10	Arachis stenosperma (O)	25	Arachis benensis(13214)
11	Arachis pintoi(4855)	26	Arachis hermannii (13251)
12	Arachis marginata	27	Arachis villouslicara (8142)
13	Arachis rigonii	28	Arachis rigoni

			(Auto tetraploid ICG -8186)
14	Arachis cruziana (12984)	29	Arachis stenosperma (8125 Auto tetraploid)
15	Arachis appressipila (8129)	30	Arachis otavio (8192)
Varietal check: VRI 2			

Table 2. Reaction of groundnut wild species against insect pests (2020-2021)

s.no	Wild species	Leaf hopper damage (%)	Mean injury rating	Resistance category	Leaf miner damage (%)	Mean injury rating	Resistance category	S.litura damage (%)	Mean injury rating	Resistance category	Helicoverpa damage (%)	Mean injury rating	Resistance category
1	Arachis kempff-mercadoi	17.57	4.0	MS	2.50	3.0	R	12.84	4.0	MS	7.71	3.0	MR
2	Arachis botizocoi (8201)	11.24	4.0	MS	2.53	3.0	R	14.91	4.0	MS	6.51	3.0	MR
3	Arachis villosa (8144)	2.72	2.0	R	2.16	3.0	R	4.20	2.0	R	1.04	2.0	R
4	Arachis cardenasii (8216)	12.93	4.0	MS	2.32	3.0	R	13.61	4.0	MS	6.98	3.0	MR
5	Arachis kuhlmannis	12.61	4.0	MS	2.79	3.0	R	12.15	4.0	MS	6.06	3.0	MR
6	Arachis correntina	8.60	3.0	MR	4.28	3.0	R	6.89	3.0	MR	2.80	2.0	R
7	Arachis helodes (8955)	3.41	2.0	R	2.04	3.0	R	4.04	2.0	R	5.03	2.0	R
8	Arachis monticola (ICG-11800)	10.13	3.0	MR	3.83	3.0	R	9.13	3.0	MR	3.38	2.0	R
9	Arachis stenosperma (HLK410)	19.21	4.5	MS	3.96	3.0	R	14.57	4.0	MS	6.96	3.0	MR
10	Arachis stenosperma (O)	14.03	4.0	MS	4.34	3.0	R	14.81	4.0	MS	6.52	3.0	MR
11	Arachis pintoi(4855)	12.33	4.0	MS	3.48	3.0	R	9.63	3.0	MR	4.59	2.0	R
12	Arachis marginata	8.38	3.0	MR	4.48	3.0	R	7.53	3.0	MR	6.88	3.0	MR
13	Arachis rigonii	18.21	4.0	MS	3.59	3.0	R	12.73	4.0	MS	6.76	3.0	MR
14	Arachis cruziana (12984)	10.44	3.0	MR	2.98	3.0	R	9.98	3.0	MR	6.31	3.0	MR
15	Arachis appressipila (8129)	8.46	3.0	MR	2.36	2.0	R	8.74	3.0	MR	4.93	2.0	R
16	Arachis duranensis	10.24	3.0	MR	3.89	3.0	R	7.37	3.0	MR	6.54	3.0	MR
17	Arachis expensis	15.98	4.0	MS	3.95	3.0	R	15.67	4.0	MS	3.99	2.0	R
18	Arachis monticola (8135)	12.89	4.0	MS	2.19	3.0	R	11.60	4.0	MS	4.43	2.0	R
19	Arachis glabrata	11.11	4.0	MS	3.98	3.0	R	11.57	4.0	MS	4.35	2.0	R
20	Arachis batizocoi(12018)	6.70	3.0	MR	1.01	3.0	R	4.80	3.0	MR	3.56	2.0	R
21	Arachis diogoi (8962)	15.20	4.0	MS	4.82	3.0	R	8.84	3.0	MR	4.95	2.0	R
22	Arachis duranensis (8202)	15.53	4.0	MS	3.67	3.0	R	9.17	3.0	MR	5.07	2.0	R
23	Arachis posilla (4897)	11.10	4.0	MS	1.59	3.0	R	6.45	3.0	MR	4.83	2.0	R
24	Arachis paraguariensis (8130)	9.17	3.0	MR	1.98	3.0	R	6.04	3.0	MR	4.54	2.0	R
25	Arachis benensis(13214)	11.23	4.0	MS	2.07	3.0	R	6.61	3.0	MR	6.31	3.0	MR
26	Arachis hermannii (13251)	9.21	3.0	MR	2.84	3.0	R	5.40	2.0	R	3.30	2.0	R
27	Arachis villouslicara (8142)	7.03	3.0	MR	2.38	3.0	R	4.64	2.0	R	4.80	2.0	R
28	Arachis rigoni (Auto tetraploid ICG -8186)	10.50	3.0	MR	2.66	3.0	R	4.97	2.0	R	6.47	3.0	MR
29	Arachis stenosperma (8125 Auto tetraploid)	13.12	4.0	MS	2.28	3.0	R	9.23	3.0	MR	4.77	2.0	R
30	Arachis otavio (8192)	13.31	4.0	MS	2.63	3.0	R	11.50	4.0	MS	6.48	3.0	MR
31	VRI 2	40.93	6.0	HS	16.25	3.0	R	18.06	4.0	MS	17.92	4.0	MS

MR-Moderately Resistant; MS-Moderately Susceptible; R-Resistant; S-Susceptible

Table 3. Reaction of groundnut wild species against major diseases (2020-21)

S.No	Wild species	Disease Scoring Scales			
		LLS (1 to 9)	**Rust (1 to 9)**	**Stem Rot* (%)**	**Root Rot* (%)**

1	Arachis kempff-mercadoi	6	8	12.4	14.2
2	Arachis botizocoi (8201)	7	9	11.5	8.4
3	Arachis villosa (8144)	1	1	3.6	2.8
4	Arachis cardenasii (8216)	8	2	15.7	17.5
5	Arachis kuhlmannis	6	2	7.6	11.5
6	Arachis correntina	7	9	7.2	15.3
7	Arachis helodes (8955)	1	2	2.5	3.5
8	Arachis monticola(ICG-11800)	7	8	14.6	11.4
9	Arachis stenosperma (HLK410)	6	2	12.5	18.6
10	Arachis stenosperma (O)	7	9	11.4	14.4
11	Arachis pintoi(4855)	6	8	16.4	7.6
12	Arachis marginata	8	9	18.6	12.3
13	Arachis rigonii	6	2	15.4	13.6
14	Arachis cruziana (12984)	6	8	11.3	11.6
15	Arachis appressipila (8129)	7	2	10.2	10.5
16	Arachis duranensis	7	2	15.6	12.5
17	Arachis expensis	8	9	16.5	13.6
18	Arachis monticola (8135)	3	3	18.4	17.4
19	Arachis glabrata	7	8	11.7	17.6
20	Arachis batizocoi(12018)	6	5	6.4	14.9
21	Arachis diogoi (8962)	8	2	7.5	7.5
22	Arachis duranensis (8202)	6	9	8.6	21.5
23	Arachis posilla (4897)	6	9	9.4	14.5
24	Arachis paraguariensis (8130)	7	9	11.6	12.5
25	Arachis benensis(13214)	8	8	18.9	13.4
26	Arachis hermannii (13251)	9	3	15.7	13.6
27	Arachis villouslicara (8142)	6	5	11.4	12.4
28	Arachis rigoni (Auto tetraploid ICG -8186)	6	2	13.4	17.8
29	Arachis stenosperma (8125 Auto tetraploid)	7	9	10.7	11.4
30	Arachis otavio (8192)	8	9	13.8	11.5
31	VRI 2 (Check)	9	9	28.3	26.5

*Mean of three replications

Table 4. Reaction of groundnut wild species against insect pests (2021-2022)

S. No	Wild species	Leaf hopper damage (%)	Mean injury rating	Resistance category	Leaf miner damage (%)	Mean injury rating	Resistance category	S.litura damage (%)	Mean injury rating	Resistance category	Helicoverpa damage (%)	Mean injury rating	Resistance category
1	Arachis kempff-mercadoi	18.32	4.0	MS	3.30	3.0	R	13.34	4.0	MS	8.21	3.0	MR
2	Arachis botizocoi (8201)	11.99	4.0	MS	3.28	3.0	R	15.16	4.0	MS	6.76	3.0	MR
3	Arachis villosa (8144)	3.47	2.0	R	2.66	3.0	R	4.50	2.0	R	1.29	2.0	R
4	Arachis cardenasii (8216)	13.68	4.0	MS	3.09	3.0	R	13.86	4.0	MS	7.23	3.0	MR
5	Arachis kuhlmannis	13.11	4.0	MS	3.54	3.0	R	11.90	4.0	MS	6.56	3.0	MR
6	Arachis correntina	8.85	3.0	MR	5.01	3.0	R	6.39	3.0	MR	3.55	2.0	R
7	Arachis helodes (8955)	3.69	2.0	R	2.79	3.0	R	4.34	2.0	R	6.78	3.0	MR
8	Arachis monticola (ICG-11800)	9.88	3.0	MR	4.61	3.0	R	9.38	3.0	MR	3.88	2.0	R
9	Arachis stenosperma (HLK410)	19.46	4.0	MS	4.73	3.0	R	13.82	4.0	MS	6.71	3.0	MR

10	Arachis stenosperma (O)	14.53	4.0	MS	5.09	3.0	R	15.31	4.0	MS	7.02	3.0	MR
11	Arachis pintoi(4855)	12.33	4.0	MS	4.23	3.0	R	9.93	3.0	MR	4.84	2.0	R
12	Arachis marginata	9.13	3.0	MR	5.23	3.0	R	7.28	3.0	MR	6.38	3.0	MR
13	Arachis rigonii	18.98	4.0	MS	4.34	3.0	R	12.48	4.0	MS	6.01	3.0	MR
14	Arachis cruziana (12984)	11.19	4.0	MS	3.73	3.0	R	10.01	3.0	MR	6.81	3.0	MR
15	Arachis appressipila (8129)	8.46	3.0	R	3.10	3.0	R	8.24	3.0	MR	6.18	3.0	MR
16	Arachis duranensis	11.99	4.0	MS	4.64	3.0	R	7.62	3.0	MR	6.04	3.0	MR
17	Arachis expensis	16.23	4.0	MS	4.45	3.0	R	15.17	4.0	MS	4.49	2.0	R
18	Arachis monticola (8135)	13.39	4.0	MS	2.49	3.0	R	11.35	4.0	MS	6.18	3.0	MR
19	Arachis glabrata	11.86	4.0	MS	4.73	3.0	R	11.07	4.0	MS	4.90	2.0	R
20	Arachis batizocoi(12018)	7.20	3.0	MR	1.31	3.0	R	5.30	3.0	MR	4.06	2.0	R
21	Arachis diogoi (8962)	15.45	4.0	MS	5.62	3.0	R	9.09	3.0	MR	6.45	3.0	MR
22	Arachis duranensis (8202)	16.03	4.0	MS	4.17	3.0	R	9.92	3.0	MR	6.57	3.0	MR
23	Arachis posilla (4897)	11.60	4.0	MS	2.34	3.0	R	6.20	3.0	MR	6.33	3.0	MR
24	Arachis paraguariensis (8130)	9.67	3.0	MR	2.48	3.0	R	6.54	3.0	MR	6.29	3.0	MR
25	Arachis benensis(13214)	11.73	4.0	MS	2.57	3.0	R	6.36	3.0	MR	6.81	3.0	MR
26	Arachis hermannii (13251)	9.96	3.0	MR	3.59	3.0	R	5.15	3.0	MR	4.05	2.0	R
27	Arachis villouslicara (8142)	7.53	3.0	MR	2.88	3.0	R	4.89	2.0	MR	6.30	3.0	MR
28	Arachis rigoni (Auto tetraploid ICG -8186)	11.75	4.0	MS	3.41	3.0	R	5.22	3.0	MR	6.22	3.0	MR
29	Arachis stenosperma (8125 Auto tetraploid)	13.37	4.0	MS	2.60	3.0	R	9.03	3.0	MR	6.27	3.0	MR
30	Arachis otavio (8192)	13.81	4.0	MS	3.13	3.0	R	11.75	4.0	MS	6.98	3.0	MR
31	VRI 2	40.60	7.0	HS	16.10	3.0	R	18.06	4.0	MS	18.10	4.0	MS

MR-Moderately Resistant; MS-Moderately Susceptible; R-Resistant; S-Susceptible

Table 5. Reaction of groundnut wild species against major diseases (2021-22)

S.No	Wild species	Disease Scoring Scales			
		LLS (1 to 9)	Rust (1 to 9)	Stem Rot* (%)	Root Rot* (%)
1	Arachis kempff-mercadoi	5	6	15.7	16.5
2	Arachis botizocoi (8201)	8	8	13.4	11.3
3	Arachis villosa (8144)	1	1	2.3	1.6
4	Arachis cardenasii (8216)	7	3	17.2	13.4
5	Arachis kuhlmannis	7	3	8.3	15.4
6	Arachis correntina	7	8	6.1	13.6
7	Arachis helodes (8955)	1	1	1.6	2.4
8	Arachis monticola(ICG-11800)	6	7	12.3	13.2
9	Arachis stenosperma (HLK410)	6	3	15.6	14.4
10	Arachis stenosperma (O)	8	8	13.2	11.6
11	Arachis pintoi(4855)	5	9	15.2	8.5
12	Arachis marginata	7	7	16.5	11.7

13	Arachis rigonii	5	3	15.4	15.3
14	Arachis cruziana (12984)	7	8	15.6	8.5
15	Arachis appressipila (8129)	6	2	16.2	11.6
16	Arachis duranensis	6	3	17.4	11.8
17	Arachis expensis	8	8	14.7	16.4
18	Arachis monticola (8135)	4	4	18.4	16.7
19	Arachis glabrata	7	7	13.4	18.3
20	Arachis batizocoi(12018)	8	4	12.3	11.5
21	Arachis diogoi (8962)	7	3	13.4	11.3
22	Arachis duranensis (8202)	5	7	18.5	19.4
23	Arachis posilla (4897)	6	8	13.3	11.2
24	Arachis paraguariensis (8130)	8	7	15.2	15.4
25	Arachis benensis(13214)	9	7	17.6	13.8
26	Arachis hermannii (13251)	8	4	16.2	12.4
27	Arachis villouslicara (8142)	6	4	15.7	16.3
28	Arachis igoni (Auto tetraploid ICG -8186)	6	3	12.3	14.5
29	Arachis stenosperma (8125 Auto tetraploid)	6	8	17.1	18.2
30	Arachis otavio (8192)	8	8	16.4	15.7
31	VRI 2 (Check)	9	9	32.5	18.4

*Mean of three replications

Table 6. Reaction of groundnut wild species against insect pests pooled mean (2020-2021&2021-2022)

S. No	Wild species	Leaf hopper damage (%)	Mean injury rating	Resistance category	Leaf miner damage (%)	Mean injury rating	Resistance category	S.litura damage (%)	Mean injury rating	Resistance category	Helicoverpa damage (%)	Mean injury rating	Resistance category
1	Arachis kempff-mercadoi	17.94	4.0	MS	2.90	3.0	R	13.09	4.0	MS	7.96	3.0	MR
2	Arachis botizocoi (8201)	11.61	4.0	MS	2.90	3.0	R	15.03	4.0	MS	6.63	3.0	MR
3	Arachis villosa (8144)	3.09	2.0	R	2.41	3.0	R	4.35	2.0	R	1.16	2.0	R
4	Arachis cardenasii (8216)	13.30	4.0	MS	2.70	3.0	R	13.73	4.0	MS	7.10	3.0	MR
5	Arachis kuhlmannis	12.86	4.0	MS	3.16	3.0	R	12.02	4.0	MS	6.31	3.0	MR
6	Arachis correntina	8.72	3.0	MR	4.64	3.0	R	6.64	3.0	MR	3.17	2.0	R
7	Arachis helodes (8955)	3.55	2.0	R	2.41	3.0	R	4.19	2.0	R	5.90	2.0	R
8	Arachis monticola (ICG-11800)	10.00	3.0	MR	4.22	3.0	R	9.25	3.0	MR	3.63	2.0	R
9	Arachis stenosperma (HLK410)	19.33	4.0	MS	4.34	3.0	R	14.19	4.0	MS	6.83	3.0	MR
10	Arachis stenosperma (O)	14.28	4.0	MS	4.71	3.0	R	15.06	4.0	MS	6.77	3.0	MR
11	Arachis pintoi(4855)	12.33	4.0	MS	3.85	3.0	R	9.78	3.0	MR	4.71	2.0	R
12	Arachis marginata	8.755	3.0	MR	4.85	3.0	R	7.40	3.0	MR	6.63	3.0	MR
13	Arachis rigonii	18.59	4.0	MS	3.96	3.0	R	12.60	4.0	MS	6.38	3.0	MR
14	Arachis cruziana (12984)	10.81	4.0	MS	3.35	3.0	R	9.99	3.0	MR	6.56	3.0	MR
15	Arachis appressipila (8129)	8.46	3.0	MR	2.73	3.0	R	8.49	3.0	MR	5.55	2.0	R
16	Arachis duranensis	11.11	4.0	MS	4.26	3.0	R	7.49	3.0	MR	6.29	3.0	MR
17	Arachis expensis	16.10	4.0	MS	4.20	3.0	R	15.42	4.0	MS	4.24	2.0	R

18	Arachis monticola (8135)	13.14	4.0	MS	2.34	3.0	R	11.47	4.0	MS	5.30	2.0	R
19	Arachis glabrata	11.48	4.0	MS	4.35	3.0	R	11.32	4.0	MS	4.62	2.0	R
20	Arachis batizocoi(12018)	6.95	3.0	MR	1.16	3.0	R	5.55	3.0	MR	3.81	2.0	R
21	Arachis diogoi (8962)	15.32	4.0	MS	5.22	3.0	R	8.96	3.0	MR	5.70	2.0	R
22	Arachis duranensis (8202)	15.78	4.0	MS	3.92	3.0	R	9.54	3.0	MR	5.82	2.0	R
23	Arachis posilla (4897)	11.35	4.0	MS	1.96	3.0	R	6.32	3.0	MR	5.50	2.0	R
24	Arachis paraguariensis (8130)	9.42	3.0	MR	2.23	3.0	R	6.29	3.0	MR	5.41	2.0	R
25	Arachis benensis(13214)	11.48	4.0	MS	2.32	3.0	R	6.48	3.0	MR	6.56	3.0	MR
26	Arachis hermannii (13251)	9.58	3.0	MR	3.21	3.0	R	5.77	3.0	MR	3.67	2.0	R
27	Arachis villouslicara (8142)	7.28	3.0	MR	2.63	3.0	R	4.76	2.0	R	5.55	2.0	R
28	Arachis rigoni (Auto tetraploid ICG -8186)	11.12	4.0	MS	3.03	3.0	R	5.59	3.0	MR	6.34	3.0	MR
29	Arachis stenosperma (8125 Auto tetraploid)	13.24	4.0	MS	2.44	3.0	R	9.13	3.0	MR	5.52	2.0	R
30	Arachis otavio (8192)	13.56	4.0	MS	2.88	3.0	R	11.62	4.0	MS	6.73	3.0	MR
31	VRI 2	40.76	6.0	HS	16.17	3.0	R	18.06	4.0	MS	17.91	4.0	MS

MR-Moderately Resistant; MS-Moderately Susceptible; HS-Highly Susceptible; R-Resistant; S-Susceptible

Table 7. Reaction of groundnut wild species against major diseases (2020-21&2021-22)

S.No	Wild species	Disease Scoring Scales			
		LLS (1 to 9)	**Rust (1 to 9)**	**Stem Rot* (%)**	**Root Rot* (%)**
1	Arachis kempff-mercadoi	5.5	7	14.05	15.35
2	Arachis botizocoi (8201)	7.5	8.5	12.45	9.85
3	Arachis villosa (8144)	1.0	1	2.95	2.2
4	Arachis cardenasii (8216)	7.5	2.5	16.45	15.45
5	Arachis kuhlmannis	6.5	2.5	7.95	13.45
6	Arachis correntina	7.0	8.5	6.65	14.45
7	Arachis helodes (8955)	1.0	1.5	2.05	2.95
8	Arachis monticola(ICG-11800)	6.5	7.5	13.45	12.3
9	Arachis stenosperma (HLK410)	6.0	2.5	14.05	16.5
10	Arachis stenosperma (O)	7.5	8.5	12.3	13.0
11	Arachis pintoi(4855)	5.5	8.5	15.8	8.05
12	Arachis marginata	7.5	8	17.55	12.0
13	Arachis rigonii	5.5	2.5	15.4	14.45
14	Arachis cruziana (12984)	6.5	8	13.45	10.05
15	Arachis appressipila (8129)	6.5	2	13.2	11.05
16	Arachis duranensis	6.5	2.5	16.5	12.15
17	Arachis expensis	8.0	8.5	15.6	15.0
18	Arachis monticola (8135)	3.5	3.5	18.4	17.05
19	Arachis glabrata	7.0	7.5	12.55	17.95
20	Arachis batizocoi(12018)	7.0	4.5	9.35	13.2
21	Arachis diogoi (8962)	7.5	2.5	10.45	9.4
22	Arachis duranensis (8202)	2.2	8	13.55	20.45
23	Arachis posilla (4897)	6.0	8.5	11.35	12.85
24	Arachis paraguariensis (8130)	7.5	8	13.4	13.95
25	Arachis benensis(13214)	8.5	7.5	18.25	13.6
26	Arachis hermannii (13251)	8.5	3.5	15.95	13.0
27	Arachis villouslicara (8142)	6	4.5	13.55	14.35
28	Arachis rigoni	6	2.5	12.85	16.15

	(Auto tetraploid ICG -8186)				
29	Arachis stenosperma (8125 Auto tetraploid)	6.5	8.5	13.9	14.8
30	Arachis otavio (8192)	8	8.5	15.1	13.6
31	VRI 2 (Check)	9	9	30.5	22.45

*Mean of three replications

Table 8. Bio physical characters of groundnut wild species

S.no	Wild species	Leaf area sq.cm	Relative water content %	Specific leaf weight (mg/cm^2)	Trichome density (abaxil) (no./0.25cm^2)	SPAD meter reading
1	Arachis kempff-mercadoi	4.05	93.30	0.02	39.3	40.8
2	Arachis botizocoi (8201)	2.29	93.90	0.03	38.3	33.5
3	Arachis villosa (8144)	2.32	90.10	0.03	53.3	31.4
4	Arachis cardenasii (8216)	4.33	91.20	0.01	46.3	44.3
5	Arachis kuhlmannis	2.46	93.90	0.03	45.6	35.3
6	Arachis correntina	2.80	94.40	0.04	36.6	35.5
7	Arachis helodes (8955)	2.24	94.10	0.04	48.3	36.8
8	Arachis monticola (ICG-11800)	2.20	94.10	0.04	37.6	34.2
9	Arachis stenosperma (HLK410)	2.39	94.10	0.03	30.6	36.4
10	Arachis stenosperma (O)	1.98	94.10	0.05	27.3	37.1
11	Arachis pintoi(4855)	1.59	90.30	0.08	31.3	36.2
12	Arachis marginata	2.00	92.40	0.05	33.3	34.1
13	Arachis rigonii	2.38	91.40	0.05	27.3	35.7
14	Arachis cruziana (12984)	4.12	91.70	0.02	30.6	32.1
15	Arachis appressipila (8129)	2.24	91.70	0.04	51.3	32.6
16	Arachis duranensis	2.14	94.40	0.05	37.3	41.1
17	Arachis expensis	2.06	94.60	0.06	34.3	37.5
18	Arachis monticola (8135)	1.65	94.40	0.05	48.3	36.9
19	Arachis glabrata	1.80	94.20	0.07	34.3	35.2
20	Arachis batizocoi(12018)	2.27	94.70	0.03	49.3	39.9
21	Arachis diogoi (8962)	2.88	90.90	0.03	36.3	37.6
22	Arachis duranensis (8202)	4.22	91.90	0.02	38.3	35.4
23	Arachis posilla (4897)	4.53	92.30	0.03	47.6	31.5
24	Arachis paraguariensis (8130)	2.72	92.20	0.04	46.6	32.1
25	Arachis benensis(13214)	2.23	91.90	0.05	45.6	31.6
26	Arachis hermannii (13251)	1.06	94.30	0.12	44.6	28.2
27	Arachis villouslicara (8142)	2.11	94.10	0.05	48.6	31.4
28	Arachis rigoni (Auto tetraploid ICG -8186)	4.18	92.10	0.02	46.6	29.8
29	Arachis stenosperma (8125 Auto tetraploid)	2.64	91.70	0.04	48.6	32.7
30	Arachis otavio (8192)	2.32	92.20	0.04	47.3	36.2
31	VRI 2	4.60	94.70	0.02	27.3	31.4

Table 9. Bio chemical characters of groundnut wild sp

Sl.no	Parameters	Arachis villosa	Arachis helodes	VRI 2
1	Carbohydrate (%)	28.82	30.53	30.95
2	Protein (%)	18.39	16.60	17.25
3	Total phenols (mg/100g)	557.53	694.72	689.59
4	Total tannins (mg/100g)	873.21	780.70	800.31
5	Total sugars (%)	3.29	5.58	4.96
6	Reducing sugar (%)	0.70	3.88	1.09
7	Non reducing sugar (%)	2.59	1.70	3.87

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Authors' contributions
CV, TKSL, ZK carried out the field and laboratory studies, and drafted the manuscript. PI, GS conceived of the study and participated in its design and coordination. KKS design the manuscript as per the GMR journal format.

Compliance with ethical standards
Conflict of interest: The authors declare that they have no competing interests.

Ethical issues: None

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